PAPER No. 305
UNIVERSITY OF CALIFORNIA
GRADUATE SCHOOL OF TROPICAL AGRICULTURE
AND CITRUS EXPERIMENT STATION
UNIVERSITY OF CALIFORNIA ... DE, CALIFORNIA

UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

AVOCADO DISEASES IN CALIFORNIA

W. T. HORNE

BULLETIN 585
NOVEMBER, 1934

IMPERIAL MYCOLOGICAL
30 AUG. 1935
INSTITUTE

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

CONTENTS

	PAGE
Introduction	3
Diseases of green stems and leaves	4
Sun-blotch	4
Tipburn	9
Mottle-leaf or little-leaf	11
Chlorosis	13
Smudgy spot	14
Anthracnose or withertip	16
Burn, desiccation, or sunburn	19
Frost or cold injury	20
Varietal resistance to cold	20
Influence of tree condition on resistance to cold	22
Prevention and treatment of injury from cold	23
Cankers	24
Dying of twigs and branches	29
Asphyxiation	29
Witches' broom and unusual structures	29
Diseases of trunks	31
Rough bark	31
Diseases of roots	31
Melanorhiza or water injury	32
Asphyxiation, apoplexy, or collapse	35
Oak root fungus	37
Root coil	38
Diseases of flowers and immature fruits	39
Abscission of flowers and fruits	39
Carapace spot	39
Thompson spot	42
Blast or citrus blast	45
Crick-side	48
Embossment	49
Ring-neck	49
Diseases of mature fruit on the tree	51
End-spots	51
Hollow fruit	55
Sunburn	57
Senility or old age of fruit	57
Lenticel cork	57
Diseases of harvested fruit	58
Rhizopus rot, black mold, or bread mold decay	58
Dothiorella rot or surface rot	60
Anthracnose rot	67
Miscellaneous fruit decays	67
Flesh darkening	69
Temperature relations of harvested fruit	72
Acknowledgments	72

AVOCADO DISEASES IN CALIFORNIA[1, 2]

W. T. HORNE[3]

INTRODUCTION

THIS BULLETIN AIMS to bring together the principal results secured in the study of avocado diseases. The work was done by the author some years ago in Cuba, and more recently at Berkeley and Riverside. Control measures are suggested whenever information is available.

Improvement of transportation facilities, increased information concerning handling, the propagation of varieties like the Fuerte adapted to shipping, and of varieties maturing at different seasons, indicate that this fruit may now become a highly important commercial crop.

The avocado appears to be more easily injured by unfavorable conditions of soil and climate than citrus fruits; and, especially in humid countries, it has its due share of parasitic maladies.

Various injuries and diseases which have been observed are not mentioned here, and some of those not included may prove, on further study, to be of major importance. Injuries evidently caused by insects and other animals are not included though they have a marked significance and in some cases resemble the troubles discussed.

The diseases affecting avocados in other countries may, in some cases, be unlike ours and merit study to the end that quarantine measures may be adopted if the situation appears to justify; but this discussion has not been undertaken in the present publication.

The peculiar responses of the avocado to climate, and to soil and water conditions, as well as the variation in behavior by different varieties, suggest that studies of the normal physiology of this plant also need to be made.

Many avocado troubles already recognized and dealt with are of a unique character and require more extended study. In continuing the work, it is hoped that numerous conditions not now understood may be conclusively explained and that adequate control measures may be developed or further perfected.

[1] Received for publication February 2, 1934.

[2] Paper No. 305, University of California Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

[3] Associate Professor of Plant Pathology and Associate Plant Pathologist in the Citrus Experiment Station.

DISEASES OF GREEN STEMS AND LEAVES

Sun-Blotch.—Sun-blotch[4] is now widely distributed in California and was observed by Dr. H. S. Fawcett in Palestine in trees from California. The disease was first described in 1928, but it had existed here for some years. There is as yet no evidence that it was brought in with any of the many importations of scions from the Central and South American countries. The disease is said to exist in Guatemala, but we have not been able to get detailed information. So far as is known, it does not attack any plant other than the avocado. It is not known to have caused the death of any bearing or mature tree, but small plants severely affected may be so depressed in vitality that they succumb to other causes.

Where pronounced, the disease profoundly modifies the habit and aspect of the tree and causes most of the fruit to be culls. In old and severe cases trees may become irregularly bent down, the branches having pendent twigs. Trunks, limbs, and older stems are crooked and bent down, from weakness at early stages of growth, with surfaces rough and prematurely aged. Green twigs show an abnormal coloring, ranging from a mere vague mottling which is not distinguishable from some conditions of normal twigs, to pale longitudinal marks or yellow spots on the green bark. The pale areas are mostly a light buff color and are somewhat depressed. These areas frequently extend from a bud for some distance up the stem, or they may appear to extend downward from a leaf base. At the beginning of a cycle of growth the whole stem may be pale, the light area being gradually narrowed into a streak above, which blends out into green tissue (fig. 2*e*). At a very early state, the pale areas of affected twigs may show some bright red color.

In some severe cases, such as occur in the very vigorous and succulent shoots developed by cutting off large trees and introducing diseased scions, extensive development of the buff areas has occurred so that the shoots are strikingly abnormal. In such cases the extensive light-colored areas frequently develop large spots of dead tissue with abundant whitish granular exudations on the surface. This gives a different aspect of the twigs and branches from the usual one which suggests merely a pronounced and premature aging of the bark. This kind of injury might, in some cases, resemble sunburn, but it has occurred in experiments where the twigs were fully shaded.

Leaves of affected trees usually appear normal, but occasionally a

[4] Coit, J. Eliot. Sun-blotch of the avocado, a serious physiological disease. California Avocado Assoc. Yearbook **1928**:27–29. 5 illus. 1928.

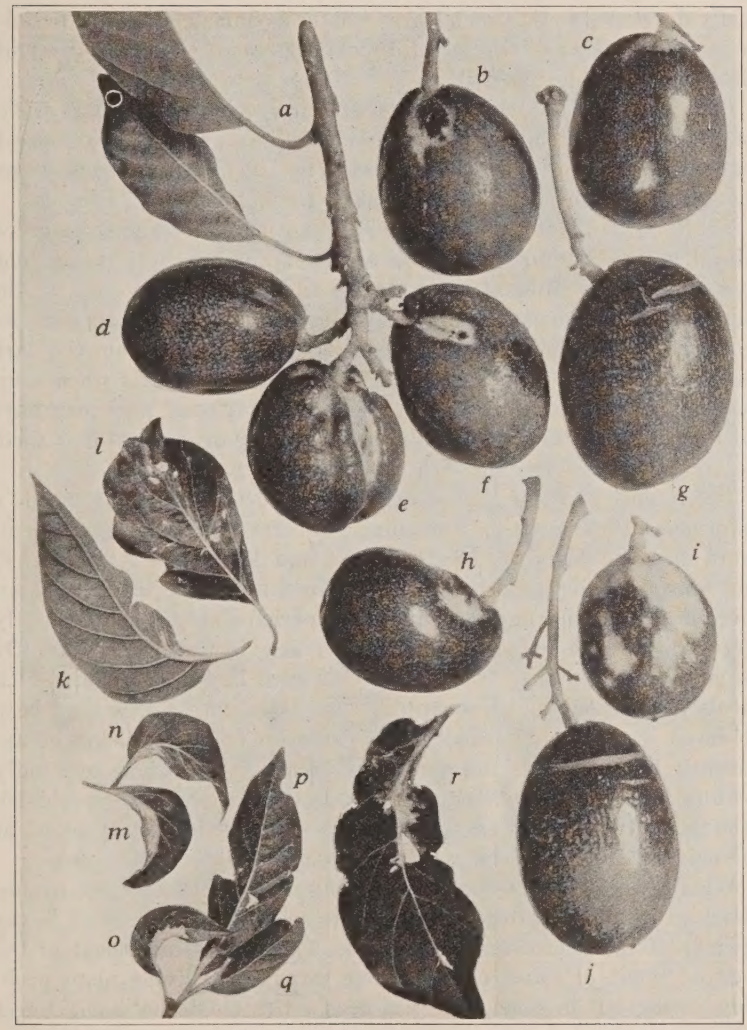

Fig. 1.—Caliente variety with sun-blotch: *a*, stem not fully normal but not showing distinct sun-blotch grooves, leaves apparently normal; *b*, large buff sun-blotch area near the stem with the center dead and dark; *c*, broad sun-blotch area near the stem and two on the side; *d*, *e*, *f*, *h*, and *i*, characteristic sun-blotch; *g* and *j*, apparently normal fruits on the same tree (the transverse cracking is not due to sun-blotch but possibly to moisture fluctuations); *k* to *r*, leaf distortion (× 0.45).

light variegation appears, the paler areas being somewhat imperfectly developed so that such leaves may be asymmetrical at the petiole, or less often they are distorted throughout, some even having two midribs (fig. 1*k–r*, and fig. 2*a*).

Occasionally a shoot is found on a healthy tree which bears variegated leaves; these shoots are true chimeras like many of the variegated-leaved plants grown as ornamentals (fig. 2*b*). These variegations, though infrequent, might be mistaken for sun-blotch.

Fruit on sun-blotched trees may be normal or variously marked with depressed lighter streaks or areas extending parallel with the long axis of the fruit. Most of these streaks and spots start at or near the stem end, but some occur well down the sides of the fruit. In varieties which remain green on ripening, color is as on the stems, but the dark varieties show brilliant purple red in the depressed parts when color develops on the rest of the fruit. Flesh of the affected part may have some lighter streaks, but is apparently not impaired for use as food, the light streaks softening with the rest of the flesh.

The intensity of the disease varies greatly. Sometimes the tree is a deformed bush suggesting a weeping mulberry, and bearing only cull fruit. In some cases the tree has good and bad twigs intermingled, and many not distinguishable as to their state. Still, in other cases, there are large and fine trees in which perhaps only a single lightly streaked fruit can be found. Shoots which are vigorous and apparently normal sometimes arise from severely affected limbs. Frequently such shoots develop sun-blotch symptoms at a later date. Cases have been observed where sun-blotched shoots came up from the trunk of apparently healthy trees; and cases have been reported where seemingly healthy trees grafted with apparently healthy scions gave sun-blotch growth. In the last two cases the trunks were presumably diseased at the point where shoots originated, and where the grafts were set.

Where affected scions are set in healthy trunks they give rise to sun-blotch growth. Also after a time suckers arising from the stock in the vicinity of the scions show the disease. The rate of movement of the inciting agent, or cause, of the disease through the living plant probably varies, but in some cases has been estimated to be about 3 feet per year.

Healthy stock grafted with diseased scions, but in which the scions failed to become established, has, in at least some cases, developed the disease. All efforts to transmit the disease by means of sap from affected trees have failed thus far.

No significant organism has been found by direct examination, or by cultures, though these studies are not exhaustive.

Fig. 2.—Sun-blotch on fruit, leaves, and stems: *a*, striking white leaf variegation from Kashlan variety with sun-blotch; *b*, Fuerte variety, possibly a true chimera or variegation not due to sun-blotch; *c* and *d*, round-type Fuertes with sun-blotch streaks (in *d*, the surface of one streak has dried and cracked, and the injuries on the pedicels are not due to sun-blotch but probably to frost); *e*, shoot of Fuerte showing two branches light at beginning of flush of growth, the slender branch above being buff with the leaf petiole at the end green, and the lower branch showing the light area narrowing to a broad streak; *f*, a shoot similar to the lower one in *e* but older; *g*, old sun-blotch shoot showing general roughness. (Photographs of *c* and *d* by D. F. Palmer.)

No method for transmitting the disease from tree to tree is known except through budding or grafting operations. It is possible, however, that other methods exist. Various sucking insects might be important in this connection as they are known to transmit certain plant diseases.

No case is known to the author in which a seed from a sun-blotched tree has produced a seedling which showed the disease from the beginning.[5] At one time it was thought that seedlings which had never been grafted showed the disease, but the histories of these trees are not fully clear.

The above-mentioned facts suggest that the disease is caused by an invisible agent, *i.e.*, that it is one of the so-called virus diseases.[6]

Control measures[7] cannot be recommended with much assurance. Complete eradication appears not practicable on account of the difficulty of recognizing the disease in its mild form. It would seem reasonable, in those trees where apparently good limbs and evidently affected limbs are both present, to remove the bad ones. Pronounced cases might be cut back severely to stimulate shoot formation, in hope that some of the shoots may prove healthy and that a new tree may be formed from these. Unless a favorable result is secured, unprofitable sun-blotch trees might well be destroyed. So far as known, a new tree may be replanted where a sun-blotch tree is removed. Occasionally, an apparently good shoot appears in a severely affected tree, and for affected trees of good size and vigor, it may be better to wait for the appearance of such shoots rather than to practice severe cutting back.

It will probably be best to remove promptly all young and inferior trees showing symptoms of sun-blotch. It is possible that trees of unusual value may be conserved, or at least some healthy propagations secured from them, if special care is taken, although this has not yet been demonstrated.

Every tree showing any symptoms in fruit or twigs should be carefully avoided in the usual cutting of scions. Mother trees from which buds and scions are to be taken should be chosen according to a carefully planned procedure of examination of the tree and fruit; both for avoiding entirely all sun-blotched trees, and to secure propagations of the best types.

Nursery trees showing sun-blotch evidently should not be planted. However, the author has not been able, in all cases, to recognize the dis-

[5] Parker, E. R., and W. T. Horne. The transmission of avocado sun-blotch. California Avocado Assoc. Yearbook 1932:50–56. 1932.

[6] Horne, W. T., and E. R. Parker. The avocado disease called sun-blotch. Phytopathology 21:235–238. 1931.

[7] Horne, W. T., and E. R. Parker. The avocado sun-blotch disease. California State Dept. Agr. Mo. Bul. 20(7):447–454. figs. 82–85. 1931.

ease, owing to incomplete knowledge of symptoms. A condition of trunks of nursery trees consisting of obscure depressed longitudinal streaks has been brought to the author's attention, and is being investigated. The effect might be described as ropiness of the trunks of trees which otherwise appear to be normal, also some yellow patches may show on the green bark. Studies have thus far failed to demonstrate that this condition is due to sun-blotch, but the trees are still under observation.

Tipburn.—Tipburn consists in the formation of more or less extensive dead areas where the leaves have died back from the outer ends. The dry area on a leaf tends to have an uneven outline and to follow back along the leaf margins. More than half of the leaf area may be involved and there is a tendency for all the leaves of approximately the same age on a shoot, or sometimes over a large part of the tree, to be about equally affected.

Where strongly developed, tipburn appears to be a rather distinct disease. However, some dying back from the tip may be found on old leaves of many trees. Accordingly, it is possible that tipburn should be understood as the name of a symptom, which may be more or less developed, rather than the name of a definite disease.

Tipburn is a condition of fully matured or old leaves, but affected leaves probably are not shed very much earlier than normal ones on trees of comparable vigor. A dying of tips and edges of very tender leaves, usually those not yet fully grown, in which the dead part is very dark, is not included in this discussion, as it has not been sufficiently studied. (See "Burn," p. 19.) The original description of tipburn[8] states that the trouble is most pronounced in trees growing in light sandy soils overlying heavy clay subsoils and situated near the coast where they are exposed to ocean winds, but that it may occur in other soils and under other conditions also.

Tipburned leaves[9] have been found to contain more salt (NaCl) than normal leaves. Excess of salt in the soil, or in the irrigation water, will undoubtedly increase the condition. Also, tipburned areas evidently have a relation to the water supply of the leaf. Plants in pots and water cultures suffer severely, probably owing to abnormal root conditions and occasional drought.

Dean F. Palmer has observed that in the most usual form of tipburn, at least a little mottling precedes the appearance of dying back of the tip and margin (fig. 3). (See "Mottle-Leaf," p. 11.)

[8] Coit, J. Eliot. Pests and diseases of the avocado: tip-burn. California Avocado Assoc. Yearbook **1928**:19. 1928.

[9] Haas, A. R. C. Relation of chlorine content to tip-burn of avocado leaves. California Avocado Assoc. Yearbook **1928**:57. 1928.

Tipburn apparently is not caused by leaf-killing fungi since the dead areas are often almost without such fungi. Where fungi do occur, they are evidently chance infections, several spots of the same or different fungi being scattered about on the same dead area (fig. 3 and fig. 30*b*).

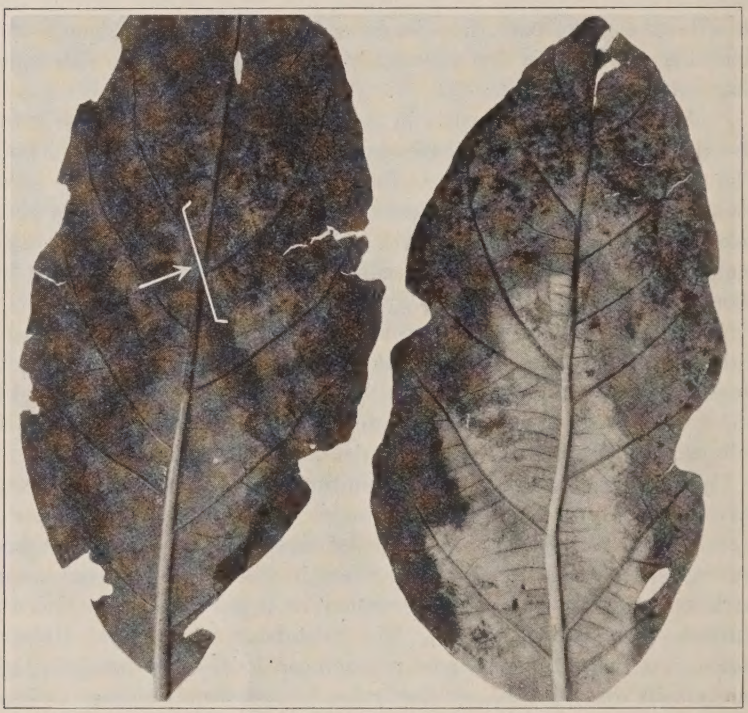

Fig. 3.—Tipburn on avocado leaves. One area of dothiorella is indicated by the arrow. The leaf at the right was photographed partly by transmitted light to show paler areas between the veins. Apparently all conditions in the orchard from which these leaves came were favorable except that irrigation water contained more chlorine than is considered safe for avocados. The dark spots in the dead portions are mainly the fungus *Cladosporium* sp.

It frequently appears that a colony of dothiorella, anthracnose, or other fungus has caused the dead area to be slightly enlarged locally.

There is general belief that tipburn is a drought phenomenon, and that it may be intensified by shortage of water, very drying atmospheric conditions, defective functioning of the root system, or general weakness of the plant. Tipburn may not come at once with acute lack of water, but may follow after several days, and when abundant water has been supplied. Trees in bad condition, furthermore, do not always show pronounced tipburn, especially in medium or heavy soils.

Tipburn should be regarded as a state of reduced leaf area, indicating some unfavorable condition—probably a defect in the quality or quantity of water. It is important because it reduces effective leaf area (severely tipburned trees often lack vigor), and also because the dead areas become invaded with such fungi as dothiorella, anthracnose, and alternaria. Spores of these fungi are freely propagated while the tipburn leaves are still on the tree, and are in favorable position to get on the fruit. While the fruit remains on the tree, or while still hard, it does not often show signs of infection, but when it softens, spots of decay appear. This applies particularly to dothiorella in the coastal region; but applies also to other fungi, and to all districts. (See Dothiorella Rot," p. 60.)

Control measures can be suggested only in general terms and based on observations of results in different orchards.

The use of irrigation water containing more than a minimum amount of salt should be avoided. About 100 parts per million of chlorine (equals 165 p.p.m. common salt) may be considered a danger line; but other conditions have much to do with the degree of injury to the tree by a specific concentration.[10] In some cases, tipburn has appeared when using water with about 50 parts per million of chlorine while in other cases good trees have been grown with water containing as much as 200 p.p.m. chlorine.

Either excessive drying or water-logging of the soil should also be avoided. It has been pointed out that the appearance of the avocado tree is not always a safe guide as to its need of irrigation. The mature leaves are rather stiff and do not show rolling or wilting on slight shortage of water. Small plants have been observed which by accident became so dry that the stems shriveled, yet the mature leaves did not show much distress except for some drooping because of the petioles becoming flaccid. When supplied with water the stems became plump again, but the leaves did not entirely resume their former position and in a few days severe tipburn developed.

The soil management program should be planned with the purpose of promoting tree vigor. The first measures to be taken are to find out whether an adequate supply of organic material and nitrogen are present.

Shelters and windbreaks are beneficial in the more exposed situations.

Mottle-Leaf or Little-Leaf.—The name mottle-leaf may probably be applied with propriety to a condition of foliage where the green coloring matter in leaves is distributed in a spotted or mottled pattern, the

[10] Thomas, E. E. Effects of chlorides in the soil on avocado trees. California Avocado Assoc. Yearbook 1932:48–49. 1932.

lighter areas being between the veins (fig. 4). It is also called foliocellosis, or frenching; in extreme cases frizzels, little-leaf, etc. In severe cases leaves become small in size and light in color and shoot growth is

Fig. 4.—A pronounced case of mottle-leaf or little-leaf on Fuerte variety.

reduced. Young leaves are abnormal from the beginning and often a bronzing can be noted before the typical mottling is fully developed. Severely affected old leaves often may have many small dead specks

and spots. Fruit on severely affected shoots is small and abnormal. This disease is not generally common in California, but tends to be severe in some cases.

A similar disease known also as mottle-leaf is of much importance on citrus fruits where it has been under investigation for a number of years.[11] On the latter host it is at present considered to be nutritional in nature but the exact cause is as yet unknown. It was previously thought to be related to the inability of citrus leaves to satisfy their calcium requirements,[12] but the recent observation showing the beneficial effects of small amounts of zinc indicate that the earlier theories were inadequate.

It is now generally believed that an abundant supply of organic material, together with an adequate supply of nitrogen, and a favorable moisture condition are important in the prevention of mottle-leaf. Recent studies have shown that mottle-leaf, in trees of several kinds, has been greatly decreased by the application of several pounds of zinc sulfate per tree to the soil or by spraying the foliage with a mixture of zinc sulfate and lime. This is being tried on avocados. It is hoped that this treatment may prove beneficial, but attention to the moisture content and organic material of the soil should not be relaxed.

Chlorosis.—Chlorosis is the name applied to a condition of foliage which has a uniform very pale-green or yellowish-white color. This is distinguished from mottle-leaf in which the same leaf has light and more or less normal areas alternating giving a mottled or spotted effect. Severely affected chlorotic leaves in time become more or less burned at the tips and edges and some have dead spots. They are evidently less resistant to drying and injury than normal leaves. Since leaves without green color cannot manufacture sugar and starch to nourish the plant, a kind of starvation results from severe chlorosis. The word is used here as the name of a symptom rather than the name of a specific disease. It is believed that the causes and remedies may not be the same in all cases.

The explanation usually given for the occurrence of chlorosis is that a certain amount of iron must be present, dissolved in the plant juices, to enable the plant cells to manufacture their green coloring matter. If an excess of lime is present in the soil it may interfere with the iron supply of the normally green parts of the plant, since it makes the iron insoluble.

Apparently there are cases where the above explanation does not apply, since chlorosis sometimes occurs where the lime content of the soil is not excessive. In some cases, at least, the subsoil is impervious and

[11] California Agricultural Experiment Station. Report of the College of Agriculture and Agricultural Experiment Station, 1913–14:62. 1915.

[12] Fawcett, Howard S., and H. Atherton Lee. Citrus diseases and their control. p. 336–341. McGraw-Hill Book Co., New York. 1926.

percolation of water is very poor. Also new foliage on avocado plants in ordinary soil in pots has come out yellow. In these cases, repotting in very porous soil generally corrects the trouble.

Nursery trees of normal color may give rise to a flush of growth which is strongly chlorotic. A bud set in a normally colored stock may grow out into a shoot without chlorophyll.

The relation of lime and of drainage to chlorosis needs to be studied further in the avocado. The partly yellow leaf (fig. 2*b*) is not affected with chlorosis, but presumably is a bud sport yielding a chimera or variegated plant. In this case the light color is presumably not related to a soil or water condition.

Control may be difficult. Chlorotic plants of other sorts have been restored to normal color by spraying with dilute solutions of iron salts. Injecting solutions of iron salts into the trunk or roots has sometimes restored normal color. The last method,[13] however, has not been found satisfactory since the effect is temporary and a certain injury is caused to the trunk by each injection. Iron sulfate has sometimes been applied in trenches to the roots of affected trees, with favorable results.[14] It is probable that mixing the finely ground material with organic matter is helpful.

The most important measure in treating the majority of cases would seem to be to avoid any excess water in the soil. The use of abundant organic material and an adequate supply of nitrogen will probably help.

Where soil is very shallow and underlaid with dense layers of soft whitish stone containing much calcium carbonate, control of chlorosis and production of good avocado trees will probably be difficult to accomplish. (See also "Asphyxiation," p. 35, "Melanorhiza," p. 32, and "Mottle-Leaf," p. 11.)

Smudgy Spot.—Smudgy or sooty spots, caused by *Helminthosporium* sp., are common on green stems of avocados. Margins of the spots are not sharply outlined but fade out. The size is from very small to large; or numerous spots may be confluent into a nearly continuous area. With a moist cloth the black material may be wiped off leaving the green bark uninjured (fig. 5, at *x*). Leaf petioles are frequently spotted and less frequently the spots occur on leaves or even on fruits. It has not been observed that the spots are appreciably injurious but they sometimes challenge attention, especially in nursery trees.

Specimens were sent to the United States Department of Agriculture, Plant Disease Survey, Washington, D. C., and the fungus was

[13] Thomas, E. E., and A. R. C. Haas. Injection method as a means of improving chlorotic orange trees. Bot. Gaz. **86**:355–362. 1928.

[14] Bennett, J. P. The treatment of lime-induced chlorosis with iron salts. California Agr. Exp. Sta. Cir. 321:1–12. 1931.

tentatively identified as belonging to the genus *Helminthosporium*. Fungi of this genus have been reported on other plants of the laurel family.

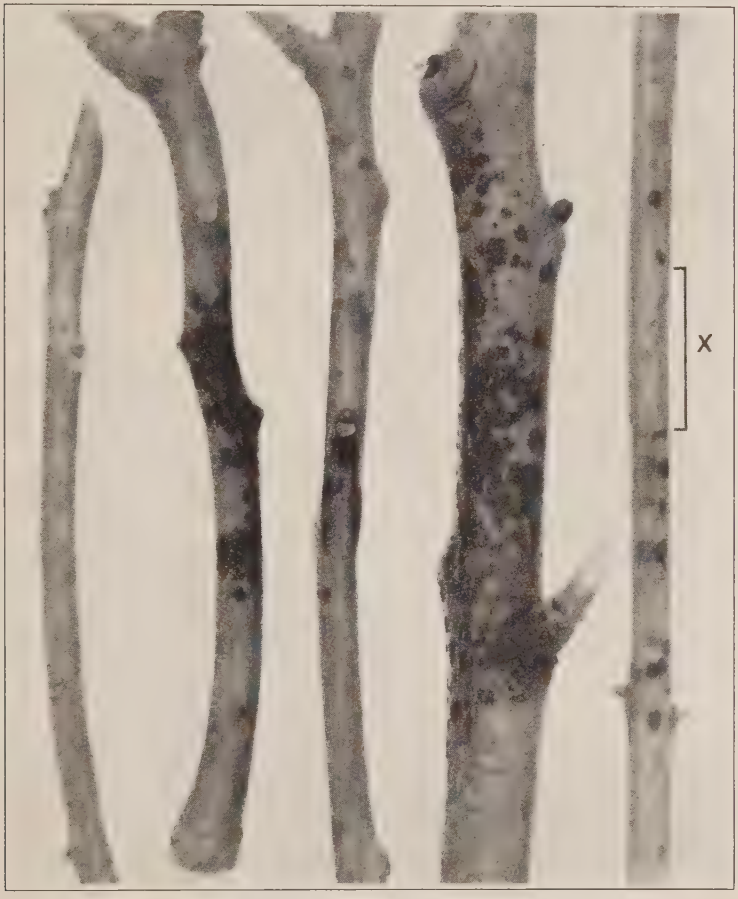

Fig. 5.—Smudgy spot on green twigs of Fuerte. At *x*, a number of spots were rubbed off, using a moist cloth.

Certain black fungi are common on many plants. These fungi live in the honeydew secreted by various insects. Careful observation has failed to connect the smudgy spot fungus with any insect, and the above name is being used to distinguish it from the so-called "sooty mold fungi" which follow attacks of certain insects.

The fungus is widely distributed on avocados in California. It is not

much restrained by dry atmosphere, as it is common at Riverside and Escondido. It apparently does no harm to tree or fruit, but may be objectionable on account of its appearance under some very special circumstances, as on nursery trees, or fruit.

When bordeaux spray has been applied, the fungus has apparently been destroyed. A colorless spray, such as ammoniacal copper carbonate, might be tried if the stain left by bordeaux is objectionable. A mixture of 2 parts cold water paint with 1 part sulfur, sprayed on the plants and washed off after two months, is said to remove the fungus. (See p. 66 for discussion of copper sprays and cyanide fumigation.)

Anthracnose or Withertip.—The word anthracnose is used to designate certain plant diseases which consist in the formation of dead spots of various sizes in living stems, leaves, or fruits.

Some anthracnose diseases, such as those affecting the foliage or fruits of sycamores, limes, mangos, and other plants, may be very injurious, especially under moist conditions. Anthracnose (withertip) of oranges, grapefruit, and most other citrus plants was formerly somewhat misunderstood, owing to confusion with a disease caused by a closely related but distinct fungus affecting limes. A clear account of these diseases as to citrus fruits has been given by Fawcett and Lee.[15] Incomplete studies indicate that in California anthracnose of avocados is caused by *Colletotrichum gloeosporioides* Penz. and closely parallels anthracnose as it affects common sweet oranges, lemons, and grapefruit. Apparently in California anthracnose of avocados as a disease affecting fruit on the tree, leaves, and twigs is unusual, except following injuries of some kind. The anthracnose fungus may occur abundantly on dead or much weakened leaves and twigs. On the soft (ripe) fruit it is one of the most frequent causes of decay. (See "Anthracnose Rot," p. 67.)

In 1928 there appeared to be danger of an outbreak of anthracnose, and as an emergency measure, the following spray program based on experience reported from Florida and other countries was suggested for trial.[16]

Spray three times, beginning early in November and repeating at intervals of six to eight weeks. Spray materials suggested were standard bordeaux, ammoniacal copper carbonate, and Burgundy mixture. It is anticipated that the bordeaux will be most effective but that the others will leave less stain on the fruit. James D. Hoffman of Pasadena and C. V. Newman of Tustin carried out this spray program using the bordeaux mixture on limited areas. Results were significant since they

[15] Fawcett, H. S., and H. A. Lee. Citrus diseases and their control. p. 283–293, 454–464. McGraw-Hill Book Co., New York. 1926.

[16] Horne, W. T. Semi-annual field tour, Orange County, October 20, 1928. California Avocado Assoc. Yearbook 1929:12–14. 1929.

showed that no harm was caused to trees or fruit by the bordeaux. However, as no anthracnose appeared in the orchards, we have no evidence concerning the effect of this spray on the anthracnose under California conditions. (See p. 66 for a discussion of cyanide injury following the application of copper sprays.)

During three years of rather careful study of avocado troubles, the author found no case of anthracnose on fruits on the tree until 1931, when fruits of the Northrup and Puebla varieties with spots in which withertip fungus was growing were sent in from Riverside and from Escondido. In both cases these fruits had been on the trees beyond the proper time for picking, both had been exposed to the November freeze, and at least the Riverside fruit had been subject to hail early in the autumn. It was not possible to state that the unusual circumstances had enabled the withertip fungus to become established, but this was believed to be the case.

In the lime, mango, and some other tropical fruits, anthracnose may cause destruction of flowers and young fruits, and it has sometimes been supposed that the excessive shedding of flowers and young fruit which occurs occasionally in the avocado is due to a disease of the same kind. The author has observed with care but has not been able to find anthracnose injuring avocado flowers in California, nor has spotting of young leaves or fruit been seen. It is stated that anthracnose of avocado flowers is rare in Puerto Rico.[17] The author failed to observe it in Cuba, but the studies were by no means exhaustive. (For a discussion of shedding of flowers and fruits, see p. 39.)

Anthracnose of the avocado merits more thorough study, but for the present it seems safe to conclude that in California it does not constitute a serious menace to avocado trees and young fruit.

In other countries, anthracnose has been reported by reliable workers as behaving differently from what is reported here for California. In southern Florida and the West Indies a disease of avocados known as "black spot" and ascribed to a fungus of the genus *Gloeosporium* or *Colletotrichum* occurs.[18]

In black spot disease young leaves, stems, and fruits are attacked as indicated by the name and much harm may be done.

In Honolulu, a disease known as "rusty blight" and ascribed to a fungus of the genus *Gloeosporium*[19] occurs and causes defoliation of trees.

[17] Nolla, J. A. B. The anthracnose of citrus fruits, mango and avocado. Puerto Rico Dept. Agr. Jour. 10:25–43. 1926.

[18] Rorer, J. B. Fungous diseases of the avocado. Trinidad and Tobago Dept. Agr. Bul. 18(3):132–133. 2 pl. 1919.

Stevens, H. E. Avocado diseases. Florida Agr. Exp. Sta. Bul. 161:3–23. 6 fig. 1922.

[19] Higgins, J. E., Chester J. Ham, and V. S. Holt. Avocado in Hawaii. Hawaii Agr. Exp. Sta. Bul. 25:23–26. fig. 2, pl. 5. 1911.

Fig. 6.—The upper leaves, *a* and *b*, show a kind of leaf shot-hole which occurs occasionally; *c* to *g*, injuries observed following periods of high temperature on leaves not fully matured; *f*, sunburn showing an extensive light area formed on one side of the midvein; *d* and *g*, similar to *f*, but with black dead spots; *e*, severe burn in which a darker band one-eighth inch wide occurs in the dead tissue next to the green.

The author has not recognized black spot disease, nor the rusty blight disease in California. Temperature, humidity, and varieties of avocados generally grown, are different in California from those in the countries mentioned. It is also possible that the strains of withertip fungi found in California may be different from those occurring in the other countries. Studies in the field following periods of prolonged rain may reveal conditions not yet observed by the author.

Burn, Desiccation, or Sunburn.—The avocado obviously is not well adapted to resist conditions which favor extremely rapid evaporation of water, namely, high temperature, very dry air, and rapid air movement. New leaves which have not attained their full maturity (as shown by thickness and stiffness) are susceptible to physical injury and to drying. In the warmer avocado districts, healthy and vigorous trees usually show a certain number of leaves which have turned dark and dried wholly or in part. The drying mostly affects immature leaves and causes them to become deformed as they expand (fig. 6*c–g*).

The period of greatest susceptibility is apparently between the time the leaf is an inch or less in length and when it has reached full size but not attained the thickness and hardness of full maturity.

Under diverse conditions of the tree, the injuries produced may show much variation. Sometimes numerous spots or small specks show (fig. 6*a, b*). A single tree and perhaps only certain leaves are affected. No significant organism has been found in the dead areas, and the blemish is thought to be a desiccation burn occurring under very special conditions of tree and environment.

The parts played, respectively, by high temperature, by desiccation alone, by wind in bending and injuring the leaf, and by the influence of conditions in the soil, is not clear. The appearance of such injuries is not confined to the times of highest temperature and strong wind, but occurs occasionally with normal summer weather. A vigorous tree is not, apparently, seriously injured by having a few burned leaves. However, shelter is one of the most important considerations in avocado culture. Trees close to heavy shelter, such as a home, often show a very healthy aspect. For newly planted trees, this protection is more important than for citrus.

Small plants which have not become fully established, or which are low in vigor, may show pale, yellowish color in the most exposed twigs, a brown, corky layer may be developed over the surface and even a killing of the bark may result.

Where limbs on trunks are weakened by an excessive crop, or otherwise, and are brought to a new or more severe exposure, the bark may be killed. Varieties like the Lyon and Puebla frequently are injured in

this way. Timely thinning of fruit appears to be indicated in this case. The avocado tree may be cut back severely when well grown, if it becomes desirable to get rid of injured limbs, and it will restore itself rather promptly.

Protection of newly-set trees until they are established, whitewashing exposed trunks and branches, and supplying abundant water at critical times, are accepted measures for reducing injury to a minimum.[20] (See also "Cold Injury," p. 20; "Tipburn," p. 9; "Sunburn," p. 57; "Abscission of Flowers and Fruits," p. 39; and "Sun-Blotch," p. 4.)

Frost or Cold Injury.—No extensive studies of the effects of cold on avocados have been undertaken by the author but a number of papers have been published on this matter.[21] It appears safe to make the following statements:

1. Symptoms on foliage and stems: where freezing is slight leaves may show small dead spots or merely specks; or lower and outer more exposed leaves may be killed at the tips. Where freezing is severe, varying degrees of leaf injury will be apparent, sometimes causing complete defoliation. Where this occurs, many twigs will be killed back from the tips. Bark of stems may be split and separated from the wood so that in healing, grotesque cankers are formed. With increasing degrees of cold, larger stems are affected until the main limbs may die and even the trunk may be killed to the ground.

2. Symptoms on flower buds and flowers: these have been reported killed when trees were otherwise not much injured, causing loss of one year's crop.

3. Symptoms on fruit: the fruit pedicels are more easily frozen than either the leafy stems or the fruit itself, the most slender part of the pedicel being most liable to injury (figs. 7 and 8). The pedicels wither and the fruit drops. If used when the pedicel first shows injury, such fruit should be perfectly good.

Varietal Resistance to Cold. — The Mexican varieties, including Fuerte, show cold resistance, varying from somewhat more pronounced

[20] California Avocado Association. Symposium on heat injury. California Avocado Assoc. Ann. Rept. 1917:94–99. 1918.

[21] Hertrich, Wm. Effect of the recent cold weather on the different varieties of avocados in different localities. California Avocado Assoc. Ann. Rept. 1921–22:16–27. 1922.

Hodgson, Robert W. The California avocado industry. California Agr. Ext. Ser. Cir. 43:38–41. Revised 1934.

Kinman, C. F. Observations on frost injury to avocados. California Avocado Assoc. Ann. Rept. 1918–19:56–58. 1919.

Ryerson, Knowles. Avocado culture in California. Part I. History, culture, varieties, and marketing. California Agr. Exp. Sta. Bul. 365:602–604. 1923.

Ryerson, Knowles. Recovery of the avocado tree after the 1922 freeze. California Avocado Assoc. Ann. Rept. 1922–23:26–29. 1923.

Webber, H. J. Cold resistance of the avocado. California Avocado Assoc. Ann. Rept. 1917–18:49–50. 1918.

than the orange to about that of the lemon. Injury may be expected even on trees of good size where conditions otherwise are favorable for resistance at 20° F. The Fuerte variety, in some ways intermediate between Mexican and Guatemalan types, is generally rated with the Mexican varieties in cold resistance.

Fig. 7—Two Itzamna fruits showing what is thought to be typical cold injury. The pedicel is injured but the fruit is unhurt. At the left the whole pedicel is darkened but the fruit was still living tissue as shown by normal abscission or cutting off of the pedicel four days after picking. At the right the lower segment of the pedicel is shown as uninjured.

The Guatemalan types present a wide range of resistance, but experience indicates that they are slightly less resistant, about the same as the lemon. Severe injury may be expected at 25° F.

The West Indian types, which occur only as occasional trees in California, are considered too tender for commercial planting. Severe injury to them may be expected at 27° F.

Seeds of hardy Mexican types are now used almost exclusively for producing rootstocks in the nurseries. If seeds of tender Guatemalan and West Indian varieties should be used, the stocks might be frozen

when the tops are not. This is especially true since temperature is likely to be lowest at the surface of the ground, and it is not customary in California to mound young trees for winter protection.

Fig. 8.—Artificial cold injury, produced by exposure for 4½ hours to a temperature reaching 26° F. The fruit was uninjured but part of the pedicel was killed.

Influence of Tree Condition on Resistance to Cold.—Owing to extreme local variations of intensity and duration of cold, both varietal resistance and resistance due to tree condition may be difficult to judge. Tree condition itself may also be a very obscure matter. Young, actively

growing leaves are easily injured. The mature leaves on trees in active growth are reported to be more easily injured than comparable leaves on trees in a dormant condition.

The young foliage, flowers, and tender fruits of all varieties and under all conditions do not have the same degree of resistance; but all are very tender.

Trees in any way weakened, or not in full vigor, are said to suffer much more than robust trees. Trees in poor or unfavorable soils, those which have become too dry (and especially if they have been dry and then heavily irrigated), and trees with bad unions, or which have been wounded or recently pruned, may be injured. Girdling is said to have a rather enduring effect in this way. Wind injury increases cold damage. Small plants and young trees suffer much more than older ones.

In robust trees, recovery from cold injury is more rapid and complete than in citrus trees. Where only leaves and small branches are lost, harm seems to be slight except for loss of the succeeding crop. Trees may make rapid recovery when frozen to the main trunk or even to the ground. However, some trees fail to recover satisfactorily and may as well be removed when it is seen that they are not doing well.

Prevention and Treatment of Injury from Cold.—For commercial groves, the matter of prevention of cold injury is probably more important than for citrus. The extensive information developed in connection with citrus groves should apply as to wrapping the trees and the use of orchard heaters.

For home-lot trees and very small plantings, orchard heating may not be practicable, but the young trees should have the trunks protected by loosely wrapping with cornstalks or similar material for several years after planting or until they become robust. The Fuerte and Mexican varieties are preferable to more tender kinds for planting in a wide variety of situations. Young seedlings of promise should be protected as they might easily be lost while young, but later the danger is much reduced.

Where trees have been severely frozen they should be whitewashed, and it will be best to disturb the new growth as little as possible for the first year. If shaping of new growth is to be done, probably the best method would be to pinch out the tips. Very little foliage should be cut away. In general, the procedure for frozen citrus trees may safely be followed for the avocado.

When the tree is reëstablished, dead branches should be cut away, the wounds disinfected and covered to prevent wood decay, and to facilitate healing. The new growth will need somewhat more care in training to secure a desirable tree than in starting with a nursery tree.

Authorities agree that the avocado may not safely be "hardened off" by severe drying in preparation for winter, but that a favorable moisture condition of the soil should be continuously maintained.

The California Agricultural Extension Service might well be consulted in making plans for frost protection in any given locality. (See "Temperature Relations of Harvested Fruit," p. 71.)

Cankers.—The word canker is used for a condition affecting stems, trunks, or roots, in which there is a dead spot of varying size and shape, often surrounded by a zone of diseased or more or less abnormal tissue. Cankers in plants are frequently caused by parasitic fungi which actively invade and kill the plant tissue when certain conditions of temperature and moisture prevail. When conditions become less favorable, the fungi may become inactive and die out. Cankers may, however, be due to other causes.

Cankers affecting avocado bark,[22] usually near the base of the tree, have been studied by Dr. Fawcett. He was able to isolate a fungus which was first thought to be a variety of brown rot organism, *Phytophthora citrophthora,* but which on later study by Dr. Barrett was found to be *Phytophthora cactorum* (Leb. and Cohn) Schroet.[23]

This fungus, when placed below the bark of healthy avocado trees, caused the same sort of canker. It did not, however, readily attack orange trees when inoculated into the living bark.

Cankers which the author has studied on avocado appear to be principally of two kinds, those affecting the base of the trees and roots, and those found on limbs and green stems.

A number of avocado cankers at the base of the tree have been observed, but only bacteria and miscellaneous fungi were found, none of which produced disease when inoculated into normal avocado bark. A case of this kind was studied with M. H. Kimball, Assistant Farm Advisor of Los Angeles County, and a considerable number of cultures were made. It is probable that in the cases investigated the primary cause of the canker was not in an active state, or had died out.

---

[22] Fawcett, Howard S. A *Pythiacystis* on avocado trees. Phytopathology 6:432–435. 1916.

Fawcett, Howard S. Bark diseases of avocado trees. California Avocado Assoc. Ann. Rept. 1916:152–154. 1917. *Also in:* California Citrograph 2(3):22–23. 1916.

[23] The genus *Phytophthora* has recently been studied by a number of authors with regard to the segregation of species and the names these should bear. According to generally accepted usage at this time a form causing crown rot of walnut in California belongs to the species *cactorum.* It has considerable similarity in structure, and effect on the tree attacked, to one of the fungi which causes lemon gum disease, first called *Pythiacystis citrophthora* but now more generally *Phytophthora citrophthora* (S. and S.) Leonian. Still a third closely related fungus is *Phytophthora parasitica* Dastur which causes a similar effect known as citrus foot rot disease in Florida and in other countries.

Fig. 9.—Inoculations made in studying avocado cankers (×1.1): *a*, inoculation with dothiorella on a healthy avocado stem in the greenhouse; *b*, inoculation using *Phytophthora parasitica* (Fawcett's culture 1792), the fungus of citrus foot-rot; *c*, inoculation using fresh tissue from an avocado stem canker; *d*, check showing manner in which inoculations were wrapped; *e*, check unwrapped; *f*, inoculation using *Phytophthora citrophthora* (Fawcett's culture 1309A) the fungus of lemon brown rot.

Both the citrus foot rot fungus, *Phytophthora parasitica* Dastur, and the fungus causing lemon gum disease, *P. citrophthora,* have been inoculated into avocado stems in the greenhouse and very decided cankers

Fig. 10.—Canker and withering of twigs in Itzamna variety. The white points on the surface of the canker at *x* suggest that fungus bodies are present; but the white points are small masses of sugary material which exudes and dries. The three twigs at the right show about the condition found in melanorhiza.

have been produced (fig. 9*b*, *f*). From this it appears probable that any one of the three species of *Phytophthora* mentioned might cause cankers at the base of avocado trees, under favorable conditions. Cankers found by the author at the crown of avocado trees have not been very large, and have not been observed to kill the tree.

What is apparently the second kind of canker has been observed on green stems. This consists of black, slightly sunken areas often an inch

Fig. 11.—Two cankers on an avocado limb before rough swelling occurred (×0.6): *a*, surface aspect; *b* as at *a*, but at *x* the surface has been cut away over the left half of the canker to show the blackened tissue beneath. At *xx* the left half of the canker has been cut away somewhat more deeply than at *x*, but not to the wood. The deeper layers of bark appear normal. The right half of the canker has had the surface of the upper portion cut away as with the left half of *x* to show the blackened subsurface tissue. At *x* and *xx* sap has exuded and dried to a white deposit.

or two long and a quarter of an inch wide. Some of these cankers show an accumulation of white granular material which is frequently referred to as avocado sugar. This may exude from small eruptions, giving the suggestion of fungus bodies. This whitish, sugary material is very common in the avocado, in connection with abnormal conditions of

many kinds, so that its presence does not usually give much assistance in recognizing the cause of the injury (fig. 10 *x*, *x*). In early stages these cankers appear to be entirely free from significant fungi, or bacteria, and inoculations made by placing some of the affected tissue in wounds in healthy avocado plants in the greenhouse have all proved negative (fig. 9*c*). Such cankers have been rather common in the more succulent varieties such as Anaheim, Panchoy, Itzamna, and Nabal, in the sandy lands of northern San Diego County. Some of these lands are now known to have an excess of water at certain times, and some have a high content of common salt. Associated with stem cankers of this kind, large, black areas with flowing outlines have appeared in green fruits.

Some of the more severely affected trees with the twig cankers have developed twig symptoms suggesting water injury or melanorhiza (see p. 32 and fig. 10). At the times when the soil was examined it appeared to be in excellent condition. The black, rough root condition of melanorhiza was not found, but a large number of the smallest roots were dead.

In some cases the limbs and trunk are very much roughened with abnormal swellings formed about centers of injury. In figure 11 two cankers are shown, apparently of this kind, but before the rough, swollen stage has been reached. A sugary material collects about such areas, exuding as liquid, and drying in the air.

The fungus dothiorella (see "Dothiorella Rot," p. 60) has been found in cankers, and is abundant in dead twigs (fig. 30*a*, *c*); but when it is inoculated into healthy twigs no canker has been produced, in the author's experiments[24] (fig. 9*c*).

From the preceding it will be evident that cankers of avocados in California are not fully understood. However, where rapidly spreading cankers are found penetrating to the wood at the crown, these should be treated by excision, as recommended for lemon gummosis. Remove the soil about the crown so as to expose the base of the trunk and upper roots and form a ridge to exclude irrigation water from the trunk. Cut away the brown, diseased bark and a strip of healthy outer bark ½ inch wide at the sides and 1 to 2 inches at the top and bottom of the diseased area. Paint the wounds and lower part of the tree with bordeaux paste. Cankers on limbs and trunk (fig. 11) which are not actively spreading might well be cleaned out and disinfected, where practicable. Attention should be given to soil moisture, and to the possible presence of injurious amounts of alkali or salt in the soil or irrigation water.

[24] A series of inoculations was made by Clayton O. Smith during the spring and early summer of 1933. A number of cultures of the Dothiorella stage of *Botryosphaeria ribis* from different host plants were used and a large number of species of plants, including avocado, were inoculated. Many of the inoculations, including some of those on avocado, gave positive results.

Dying of Twigs and Branches.—Where the avocado tree is favorably situated it usually makes a dense and very heavy foliage. There is a tendency for branches to bend down so that the mass of foliage becomes much crowded. In some cases the trees drop nearly all their leaves at blossoming time, but apparently this is not the case with very vigorous shoots. No careful studies are known to the author on longevity of avocado leaves, but apparently leaves on strong shoots may persist for more than one year. It seems probable that many twigs die from shading in competition with other twigs. Some dead twigs evidently have not died from lack of light. Whatever the cause, a thrifty avocado tree is usually found to accumulate much interior dead brush.

While the twigs are dying, many puzzling conditions appear. Sometimes there is a strong suggestion that canker-producing fungi are active. However, considerable time spent in examining these twigs convinces the author that their dying is a normal occurrence, not caused by harmful agents such as fungi, but something in the nature of natural pruning. The dying of twigs usually occurs more rapidly at the time of blossoming and during desiccating winds.

Dothiorella, anthracnose, alternaria, and many other fungi quickly become established in the dead twigs and form their spores abundantly for infection of the fruit or for invasion of other weakened tissues. (See "Dothiorella Rot," p. 60.)

Asphyxiation.—Asphyxiation affects leaves and small twigs, and when severe, the whole plant, so that it might seem proper to discuss it at this point; but since it is most probably caused by conditions in the soil, the discussion is given with the root diseases. (See p. 35.)

Witches' Broom and Unusual Structures.—Abnormal growths are found occasionally in avocado trees (fig. 12). The infrequent occurrence suggests that these are not important, but represent deviations from normal development. Their cause is not understood.

The witches' broom (fig. 12*i*) occurred on one of the older Fuerte trees at the Citrus Experiment Station. The broom consisted of twigs somewhat thicker than normal with small leaves and making up a rather dense mass of foliage about 2 feet broad by 4 feet long. This tree has a small amount of sun-blotch and it appears that a twig, abnormal and constricted by sun-blotch, may have developed in this way owing to disturbance of nutrition in the terminal part. Scions from the abnormal growth failed, and the whole broom was lost through breaking of the stem on which it was formed. There is reason to believe that these witches' brooms are not caused by parasites but are of the nature of bud sports, and need no treatment beyond cutting out.

The abnormal growths (fig. 12*e, f*) may be of different character and

Fig. 12.—Abnormal or peculiar structures of the avocado: *a*, fasciation of stems of the Egas variety; *b*, fasciation on the Carchi variety; *c*, seedless fruit ("cuke," "unfertilized fruit," "pickle") which has developed peculiar pointed talon-like outgrowths; *d*, Fuerte fruit which has been transformed into a large misshapen and woody body; *e*, witches' broom of avocado suggesting tubers of artichokes; *f*, avocado shoot intermediate in character between the forms shown at *e* and *i*; *g*, avocado seedling showing normal fleshy white scales on the lower part of the stem, indicated by the arrow, and older roots with white rounded outgrowths; *h*, four seedlings having all or portions of certain leaves composed of thick white tissue; *i*, parts of an extensively branched witches' broom on a Fuerte tree; *x*, tip of the stem shown at the left of this group of four; *xx*, stems showing abrupt changes in diameter.

due to different causes. The peculiar irregular leaf growth[25] (fig. 12*h*) appears to be a kind of tissue usually confined to the scales on the earliest formed part of the stem but occasionally formed on later leaves also. The structures indicated by the arrow (fig. 12*g*) are normal and their correspondence with the irregular white structures (fig. 12*h*) has not been proved. Certain abnormalities are shown in figure 12*c* and *d*. Their occurrence is very rare. The white, rounded, callus-like outgrowths (fig. 12*g*) are formed regularly on roots of plants kept in water cultures. Outgrowths of this sort are common on other plants, either on roots or stems, kept under excessively moist conditions. There is probably a connection between structures of this character, and roughness of roots observed in melanorhiza. (See "Melanorhiza," p. 32.)

Fasciation or pronounced flattening and enlargement of the stem occurs on many plants (fig. 12*a, b*). The cause is not known in most cases. The so-called Chota Valley varieties growing at the Citrus Experiment Station are severely affected. They have been examined for insects, fungi, and other possible causal agents without success.

DISEASES OF TRUNKS

Trunk cankers are discussed with other cankers, page 24. Information concerning wood decay of the avocado in California appears to be very meager.

Rough Bark.—Trunks of well-grown trees sometimes show areas a foot or more in diameter where the bark is rougher than elsewhere. The appearance of these areas suggests that the bark is aging more rapidly in the particular locations than elsewhere. No detailed study of this has been made. It has been suggested that the condition is associated with sun-blotch, but it has not been established whether growth from scions set in these areas, or shoots arising here, will show the disease. It has been the opinion of some that the condition appeared following certain cold winters.

DISEASES OF ROOTS

It appears that health of the root system of the avocado is more capricious than that of any other of our common fruit trees. Many of the small roots are often black and disorganized, while the top remains in at least moderate health. Cankers of a definite type may occur on crowns and large roots. These are discussed under "Diseases of Green Stems and Leaves."

The development and character of the avocado root may be observed by suspending an avocado seed at the surface of a jar of water; or seeds

[25] Hodgson, Robert W. An avocado monstrosity. Jour. Heredity 8:557–558. fig. 7. 1917.

may be grown in moist moss or loose soil and the soil shaken out. When such roots are examined they are found to be large, long, and freely branching. Under old trees which have not been cultivated for some time root growth is abundant in the surface soil or mulch. Roots of various sizes may be closely tangled, but the very small ones are distinctly less densely matted than are citrus roots under similar conditions. Statements are frequently heard concerning avocado rooting habits such as, "The avocado is shallow rooting," etc. No careful studies have been made on the distribution of avocado roots in the soil; or, have the physical and chemical relations of the roots to the soil been fully investigated, though some work of this character is now under way. Evidently the root system tends to be very extensive, and aeration is important. (See also "Root Coil," p. 38.)

Melanorhiza or Water Injury.—Practically all horticultural treatises on the avocado call attention to the necessity of a well-drained soil for this tree. It is probable that a number of fairly well defined conditions of ill health are more or less related to an unfavorable soil moisture condition. (See "Tipburn," p. 9; "Mottle-Leaf," p. 11; "Chlorosis," p. 13; "Cankers," p. 24; "Asphyxiation," p. 35; "Thompson Spot," p. 42; and "End-Spots," p. 51.)

A certain decline of avocado trees has been observed by the author, and is here given the name melanorhiza. This is the trouble formerly called "water injury."[26]

The symptoms, while vague, present a fairly definite process of deterioration, so that we may regard the condition here described as a specific disease. The studies thus far made by the author consist in examinations of isolated trees or small groups at widely separate points in Cuba and California; and of potted plants grown for experimental use. Culture studies, inoculations, and histological examinations of a preliminary kind only have been made. In addition, a few potted avocado plants have had their roots wholly or partly submerged in water to observe the effect of artificially produced soil saturation. The result of fully submerging the roots corresponded with the disease called "Asphyxiation" (see p. 35) rather than with melanorhiza. Partial submergence gave a result more nearly like melanorhiza (figs. 13 and 14).

Symptoms consists in a decline of the branch tips. The leaves become pale and unhealthy, dropping from the tips of the shoots first, and continuing backward. Stems wither gradually from the tips. Usually the whole tree is dead after a few weeks or months. If injury is not too se-

[26] Horne, W. T., E. O. Essig, and W. B. Herms. Plant disease and pest control. California Agr. Exp. Sta. Cir. 265:17. 1923. In this, and two later editions, the trouble is referred to as "soil or water injury," which in the 1930 edition is simplified to "water injury." (Out of print.)

vere only a part of the tree may die, or a part may merely show distress. Small roots are dead and disorganized. Larger roots are dark, with rough surfaces (fig. 13). Bark of stems or roots when cut may show various stages of decline, from seemingly normal to a dark reddish color, and

Fig. 13.—At left, avocado roots from trees showing melanorhiza. At right, normal avocado roots.

water-soaked. Some bark, not visibly abnormal when first cut, turns dark rather rapidly on exposure to the air.

No apparently significant organisms have been found in the declining tissues by examination or cultures. Inoculations with the diseased bark into healthy avocado trees, under normal conditions, have always failed to initiate any similar deterioration in the healthy bark. The possibility remains that the trouble is due to a specific organism, or group of organisms, which becomes active and effective under certain conditions; or, to deleterious substances formed under conditions of deficient oxygen supply.

History of the cases has uniformly shown that the ground was saturated with water during considerable periods some weeks before de-

cline appeared. The symptoms described have been found only with soils having subsoils dense enough so that saturation may occur with excessive rain or irrigation. Trees frequently attain advanced age before being affected.

In Cuba the trouble was noted on soils judged to be of the "Havana Clay" and "Pinar del Rio" groups.[27] In both situations citrus trees were growing in excellent health near the dying avocado trees.

The trouble was not observed in soil of the "Matanzas Clay" type which constitutes most of the red land of west-central Cuba. The Matanzas clay soils are notable for free drainage, whereas the other soils mentioned have distinct subsoils and may become water-logged in times of excessive rain.

In California, melanorhiza has been rather common. Two cases which occurred in diverse soil types are notable. From accounts received concerning the original Taft tree and from examination of the mother tree of the Duke variety, the author is convinced that these trees were both lost on account of the disease here described, and that their loss might have been avoided.

In growing avocados in pots for experimental purposes, considerable difficulty has been experienced in keeping them in health. At one time a set was watered by placing the pots in pans and filling the pans with water. Under this treatment many plants gradually became unhealthy and after a time failed. When the roots of such plants were examined most of them were dead. The top of one of the plants (fig. 14) remained reasonably healthy during the experiment. The lower part of the root system was completely dead and showed rough outgrowths. (Healthy roots growing in water culture regularly form rounded, white, callus-like outgrowths as in fig. 12*g*.) Above the zone of complete saturation new roots were formed though many had died.

Control for this trouble must apparently consist in preventive measures. Trees showing advanced symptoms can rarely be saved. Cutting back, or other treatment, of the tops will probably be futile. Measures to get rid of excess soil water should be applied promptly if water injury is suspected or feared. However, permitting the soil to become excessively dry would no doubt interfere with the formation of new roots and so prevent any chances which might exist for recovery. While the problem is one of reducing soil moisture, it would seem desirable to allow all foliage to remain on the tree. When, however, a normal condition of moisture and aeration is restored in the soil, it may be best to remove all sickly foliage and branches.

[27] Bennett, Hugh H., and Robert V. Allison. The soils of Cuba. 410 p. Tropical Plant Research Foundation, Washington, D. C. 1928

Melanorhiza is probably the most serious menace to avocado trees, except in freely drained soils. Nevertheless, it is believed that it can usually be avoided, even in very heavy lands and those with dense sub-

Fig. 14.—Root of an avocado plant grown in a pot which was set in a pan and watered by filling the pan with water. The upper part of the root system was above the area of complete saturation. In this area many small roots died but new ones continued to be formed. The lower roots, exposed to complete saturation for a considerable part of the time, were dead and dark, with rough surfaces. The top remained in fair health. (See also fig. 12*g*.)

soils, provided irrigation is managed with sufficient care, and if run-off of rainfall is adequately provided for.

Asphyxiation, Apoplexy, or Collapse.—Asphyxiation[28] is the name applied to a serious disease of avocados affecting certain branches, whole limbs, or the entire tree. Leaves dry up without dropping, fruit withers, and stems die back to greater or less extent. The disease develops so rapidly that it may be regarded as a form of collapse. Usually

[28] J. Eliot Coit gave the name apoplexy in the California Avocado Association Yearbook, 1928, p. 20. Later at the suggestion of Dr. Walter Scott Franklin of Goleta, he proposed to call it asphyxiation. Since the disease appears to be connected with an unfavorable condition of aeration in the soil, the latter name is being used.

the thicker stems and limbs remain alive, and, after a time, vigorous new growth is put out so that the tree tends to restore itself rather rapidly.

The cases examined by the author had passed the earliest stages. The study of leaves, twigs, limbs, and trunks of trees affected, has failed to disclose any active agent which might cause the collapse. The larger roots appeared normal, but many of the smaller ones were dead.

The trouble appears mainly in heavy soils and follows heavy rains in the spring, although some cases have been reported in midsummer.

Collapse is known in other trees, notably in the apricot. Where a fermentation follows the collapse, it is called "sour sap."

Dr. Coit has recently made observations confirming the idea that asphyxiation is related to the air and water condition of the soil. He suggests that the trouble is a simple killing of the smaller roots by lack of oxygen when air is excluded by complete wetting of the surface layers of the soil. When stress of water shortage develops, the impaired roots are unable to supply water to the leaves rapidly enough, and the tree collapses.

In order to get a tentative idea of the effect of saturation of the soil on the avocado, two healthy potted plants were immersed in jars of water so that the soil was below the surface of the water. For a time the plants seemed to thrive, but after about 18 days both wilted. They were removed and the soil allowed to dry to normal, but the leaves remained wilted. Leaf area was then reduced and every effort made to secure recovery, but after considerable time both plants failed.

In order to compare the behavior of avocado trees with that of citrus trees when the roots are deprived of air, two orange trees in pots were treated similarly to the avocados just described. After about two months one showed serious, and one, moderate distress. The plant most seriously affected was removed and the soil allowed to dry out to a normal condition. Some of the branches died back, but the plant finally recovered and became normal. The other remained submerged for a year and a half and was in a fair state of health although with limited growth. This experiment apparently confirms frequent field observations which indicate that the avocado is more easily injured by saturation of the soil than are citrus trees.

Two other avocado plants were treated as the first set above, except that black paper was laid loosely over the tops of the jars. This was to exclude the light, and to check the development of green algae which grow when sunlight is not excluded. In the sunlight small bubbles are given off from the green algae. The bubbles are presumably oxygen. The plants wilted in 11 and 13 days, respectively. As in the first set, these plants also finally died.

Examination of the avocado roots some time after wilting, but while they were still apparently giving some promise of recovery, showed that the small roots were dead but the larger roots appeared about normal, not black and rough as in old melanorhiza cases in the field.

The trouble is believed to be due to conditions brought about in the soil by exclusion of air, and not to water directly. When air is excluded, the supply of oxygen is reduced. An adequate supply of oxygen appears to be very important to the life processes of avocado tissues (see "Melanorhiza," p. 32). Precise observations have not been made of the early stages of decline in the deteriorating roots. The disease is a serious one in some situations and merits more study, as results to date are not conclusive but suggestive only.

Prevention would seem most likely to be accomplished by measures for preventing excessive wetting of the whole soil area. Applying water only to the alternate spaces between tree rows at each irrigation might be tried. Provision for prompt run-off of rain water should be made. Treatment of the top of the tree in light cases consists in cutting back the dead branches to the framework or to good plump live bark, and painting the entire tree with white water paint to prevent sunburn. Many severely affected trees make a prompt and satisfactory recovery, but under some conditions are subject to future attacks.

Oak Root Fungus.—The oak root fungus, *Armillaria mellea* (Vahl) Quel., has destroyed many trees and shrubs of various kinds. Comparatively little complaint of injury to avocado trees has been reported. It is known that avocados are sometimes attacked and killed (fig. 15), but it seems that they are less liable to attack than citrus, English walnut, pepper, and some other trees. It is possible that more avocados will be affected as the plantings grow older, but this does not seem probable. In some cases trees of various kinds which die from armillaria are being replaced with avocados.

The disease is local. It works slowly, but areas of infection enlarge from year to year. The fungus is rather easily recognized by yellowish-white, fan-shaped fungus plaques *in* and *under* the bark (not visible *on* the surface). The spread of armillaria can probably be checked in avocado orchards by treating the soil of affected areas with carbon bisulfide. A standard dose may be counted as 2 ounces applied in holes spaced 2 feet apart each way, and 1½ feet deep. Success will probably depend on having the soil comparatively dry before injecting the chemical. This method may be expected to kill all plants (including the affected trees) growing in the treated areas, although it has not always done so in all cases.

Trees in early stages of injury may be preserved and perhaps cured

by uncovering the larger roots, removing infected bark, painting the wounds with bordeaux paste, and keeping the crowns as dry as practicable by leaving the excavation open.

Root Coil.—When young avocado plants are kept for some time in pots, the roots become curved and much crowded. It was early observed

Fig. 15.—Group of sporophores of *Armillaria mellea* on young avocado tree.

that if plants were held in pots too long, subsequent growth was seriously impaired. Present nursery practice does not involve the use of pots. Sprouted seeds are transferred directly to the field nursery. Plants with much-crowded roots may sometimes continue to grow in a healthy way for a while, but usually they lose vigor and many of the small roots die. The trouble is probably due to some unfavorable condition of the soil rather than to the crowding.

It is possible to start seeds and grow the plants for a time in pots, provided a sufficiently well-aerated soil is used and the plants are not held in the pots for too long a time. F. O. Popenoe,[29] has described a method by which seeds may be grown in pots and transferred to the nursery. A considerable advantage is secured in transplanting from

[29] Popenoe, F. O. Growing an avocado tree. California Avocado Assoc. Ann. Rept. 1916:160–164. 1917.

pots under some conditions. The injury from some curling of the roots has been exaggerated. Plants send out new roots when transplanted, and ordinarily grow satisfactorily if they have not been held too long in the pots.

DISEASES OF FLOWERS AND IMMATURE FRUITS

Abscission of Flowers and Fruits.—The avocado tree frequently produces great numbers of flowers. The branching stems of the flower clusters may form abscission or separation places at any point of branching. When the fruit is formed, separation may also occur between the stem and the fruit. The separation itself is due to changes in the plant cells along the plane where separation later takes place. Causes for the starting of these changes are obscure. External conditions, such as unfavorable temperature, excessively dry atmosphere, especially if combined with deficiency of soil moisture, or various other influences, presumably have an important effect. The whole crop of flowers may be abscised and lost; or the fruit may drop either while small or after attaining full maturity.

During the process of shedding, many peculiar conditions may be observed. In figure 16*a* and *b* it appears that the lowest pedicel segment fails before either the fruit or the rest of the pedicel. This feature has not been given adequate study, but sometimes ring-neck is strongly suggested. The only thing to be done to avoid excessive shedding, apparently, is to maintain trees in the most normal condition possible, and to avoid injury, or prevent exceptional conditions. Loss of flowers and young fruit owing to fungus attack has not been observed by the author. (See "Anthracnose," p. 16.)

Carapace Spot.—The name "carapace spot"[30] is used to designate certain conspicuous corky blemishes on avocado fruits. In the most typical form, affected areas are extensive with some of the boundaries rather straight. The surface is brown and dry and broken into somewhat angular divisions suggesting the pattern on a turtle's back. Only the skin or shell is involved. There is considerable variation in the surface figure, according to the age of the fruit when the spot is initiated, and the thickness of the shell of the variety concerned (figs. 17 and 18).

The earliest and most typical cases originate where the very small fruit comes in contact with some object such as a stem or the side or edge of a leaf. The surface of the fruit is at this time exceedingly tender and easily injured. It becomes covered with a thin, dry, smooth, light-brown

[30] Horne, W. T. Carapace spot. California Avocado Assoc. Yearbook 1929:129. 1929.

Also in: California Avocado Assoc. Yearbook 1931:82–83. 1931.

superficial layer (fig. 17). This surface layer expands less readily than the normal surface and as the fruit grows it becomes cracked, finally assuming the typical pattern. The object with which the fruit has been in contact is frequently clearly recognized. Growth of the fruit pedicel is rapid in early stages and a succession of slightly different carapace

Fig. 16.—Young Blake fruits (*a* and *b*), showing result of abscission in early July. Lenticel cork on the surface of an Anaheim fruit is shown at *c*.

spots are often present on a fruit caused by contact at a different point with the same object.

A great variety of blemishes of the general nature of carapace is to be found. Some of the latest formed are those in which a fully grown fruit striking against a limb gives rise to small isolated dark spots where the tops of the little elevations making up the pebbly surface are bruised. For the later and more evident blemishes, owing to surface bruising, the term "rubs" or "limb rubs" will probably continue in use. For the earlier, more extensive blemishes, and especially those in which regular patterns are produced by cracking, the name "carapace" may be useful.

Many features of carapace remain to be studied. The young avocado fruit will endure many sorts of wounding and continue to grow without

Fig. 17.—Newly formed carapace spots on young fruits (approx. × 2) : *a* to *e*, young fruits of the Anaheim variety from which the floral parts are about all shed. At the outer end in *a*, the small carapace has been artificially colored to make it more conspicuous. In *d*, the thickest part of the fruit is well covered with carapace. The arrow in *c* indicates the stigma which is not yet shed, marks the center of the fruit, and shows that the young fruit is distinctly oblique or unsymmetrical. In *f* to *h* are young fruits of the Blake variety showing carapace spots beginning to crack into the characteristic pattern. (Photographs by E. C. Raby.)

abscising. The author has not produced a typical carapace by artificial injury, but a very near approach was secured by two students of the summer session in 1931 (H. F. Oldham and H. W. Barnes), by rubbing a tender Ganter fruit with the side of a pocket comb. They observed that injuries which break or remove the outer surface do not produce typical carapace. A certain darkening of the surface could be observed

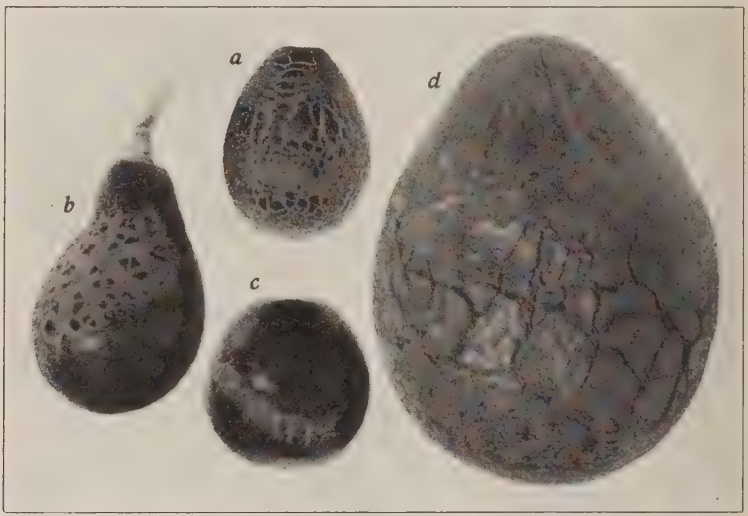

Fig. 18.—Carapace spot: *a*, on a young Spinks fruit; *b*, on Blake; *c*, on Mexicola; *d*, on a large Guatemalan seedling.

within 5 minutes after rubbing the fruit. This had something of the aspect of oil spot in oranges, but it later turned dark brown. Development of the corky layer was not discernible until some time later.

Prevention of carapace would seem to be difficult. It was observed that Fuerte fruits are less frequently affected than those of varieties with more crowded foliage. Where there is an overload of young fruits, some fruits with carapace might be cut down early. Protection from wind should reduce fruit scarring, especially of grown fruit, and also probably to some extent the more typical carapace. Flesh below a carapace spot is usually uninjured, but in some cases development is slightly retarded so that the fruit is somewhat deformed.

Thompson Spot.—Thompson spot is a name here used to designate certain rather large, black superficial spots which appear on immature fruits (fig. 19). Most of the studies have been on a few trees of the Thompson variety in one orchard. These Thompson trees appear to be entirely normal and in excellent health and vigor. They usually set

good crops, but nearly all the fruit is lost before maturity from this trouble. Reports of the Thompson variety in other localities are variable. Some trees mature their fruit normally and others, at least sometimes, show the spot described here. The variety is a good one otherwise, when this trouble does not appear. Several other varieties in this same

Fig. 19.—Fruits of the Thompson variety, fully grown but immature, showing Thompson spot. In *a*, the flesh below the spot is turning dark but is not softened at this stage; *b*, an unusually narrow fruit, green in color, the spot black, and having near its center a white granular deposit. This was at about the same stage as *a*; *c*, the same condition as *d*, having two large black spots near the lower end, each with white granular deposits. Secondary dark decline has advanced to involve more than half the fruit.

orchard are also in excellent condition and have produced unusually well, with the disease so rare that it is negligible.

The spots appear mostly on the apical end (lower or larger end) of the fruit, but not in a fixed area as with some other defects. Spots are usually about circular and mostly an inch or more in diameter. Fruits still in the "June-drop" stage, and larger, are affected. The manner of enlargement of the spots has not been determined and usually there are no concentric or zonate markings. There are frequently accumulations of white granular material as described under "Cankers," page 27.

At first the area affected is black and evidently dead, only the surface of the rind being affected. Gradually the surface dries and decline appears in the flesh below. It has not been possible thus far to discover

any organism in the injured tissue which might be the cause of its death. After a time, the affected surface dries and cracks. Common decay organisms (largely bacteria) penetrate to the flesh and decay becomes established. Many affected fruits drop. Some continue to hang on the

Fig. 20.—Citrus blast on avocados: *a*, spots of dead tissue of the kind from which blast bacteria were isolated. Some fruits show areas entirely crusted over by confluence of dead spots, and with characteristic cracking which suggests carapace spot (see p. 39). In *b*, are shown distinct spots of rot about punctures made in inoculating young avocado fruit with the blast bacteria. (Studies and photographs by C. O. Smith.)

tree, sound in the upper part, but with the lower end involved in offensive decomposition with dripping of turbid liquid.

This moist decay in avocados is not confined to the Thompson spot, but there are probably a number of fruit breakdowns in which a similar program of decomposition occurs. Below a surface injury very immature flesh may undergo a change similar to the softening of mature fruit, and decay organisms thrive in the modified flesh. The result is an offensive, moist decay.

Blemishes having some resemblance to Thompson spot have been

found on various varieties and it is possible that this is identical in character with canker spots mentioned under "Cankers." A serious fruit breakdown which has sometimes caused loss in the Challenge variety may be similar to Thompson spot, but has been observed at a later stage in the development of the fruit.

Wherever there is a heavy set of avocado fruit many peculiar spots appear on the fruits which are shed; spots of decline develop on crick-side fruits (see "Crick-Side," p. 48), and ring-neck depends on a death of tissue, which has not yet been explained (see "Ring-Neck," p. 49). Thompson fruits have sometimes been observed with areas over the upper part of the fruit much resembling ring-neck.

Some experiments in treating the soil with various fertilizing and modifying materials are under way, but no results have yet appeared. There is some indication that the trouble is associated with succulence. The less vigorous trees with heavier crops of smaller fruit have been less seriously affected than the more succulent trees with a few large fruits. One of the experiments which should be tried at an early date is to reduce the amount of water applied as much as is safe on some trees.

Blast or Citrus Blast.—The citrus blast disease caused by *Bacterium syringae* (van Hall) E. F. S.[31] on citrus plants consists in the dying of areas of green tissue, usually not very large, and of varying size. Affected areas become watery, rapidly undergo a limited rot, turn dark, and dry out as soon as atmospheric conditions permit. The dried-out areas are hard and dark, or sometimes reddish. Active development of blast is confined to periods of moist and rather cool weather. The disease[32] was recognized, and studied, on oranges in the Sacramento Valley in 1916, and was further investigated in 1917.[33] The name *Bacterium citrarefaciens* was given to the causal organism in 1917.[34] Four years later it was found that the bacterium causing citrus blast was the same as that causing the black pit disease[35] of lemons, and named *Bacterium citriputeale.*

It now appears that black pit of lemons, citrus blast, gummosis of cherries and apricots, and lilac blight are all caused by bacteria which

[31] Some of the other names which have been given to this organism are: *Bacterium citriputeale,* C. O. Smith; *Pseudomonas citriputeale,* C. O. Stapp; *Phytomonas citrarefaciens* (Lee) Bergey *et al.*

[32] Coit, J. Eliot. Citrus blast— a new disease in California. California Univ. Jour. Agr. 3:234–235. illus. 1916.

[33] Hodgson, R. W. Citrus blast—a new bacterial disease. California State Comm. Hort. Mo. Bul. 6:229–233. illus. 1917.

[34] Lee, H. A. A new bacterial disease of citrus. Jour. Agr. Research 9:1–8, illus. 1917.

[35] Fawcett, H. S., W. T. Horne, and A. F. Camp. Citrus blast and black pit. California Citrograph 6:234. illus. 1921.
Smith, C. O. Black pit of lemon. Phytopathology 3:277–281. illus. 1913.

present only minor differences, and it is possible that all might be referred to the same species.[36] If this view is accepted, the name for this species becomes *Bacterium syringae* (van Hall) E. F. S., since the name *syringae* was given to the lilac blight organism in 1902. The citrus blast bacterium in this inclusive sense occurs in the western and Mediterranean countries of Europe, the Pacific coast of North America, and in Australia.

The citrus blast bacterium[37] was isolated from certain dark spots in avocado fruits, and similar spots were produced on green tissues of fruits, stems, and leaves of avocado. The organism was isolated from Knight, Blakeman, Taft, and Queen varieties—all varieties which would have immature fruit during the winter rainy season. It was isolated from black, water-soaked, or somewhat hardened areas, and from black, depressed areas surrounding the lenticels. C. C. Lindegren[38] also isolated the organism from spots on avocado fruits.

From the foregoing there seems no doubt that citrus blast attacks the avocado, causing dark spots in the skin of the fruit (fig. 20). It has seemed desirable to have some further information concerning the frequency of occurrence and abundance of the disease on avocado fruits. Such fruits as have come to hand have been examined, but in no case has the citrus blast bacterium been isolated by the author. However, intensive study has not been made during or immediately following prolonged rainy periods. The principal method used has been to insert a piece of tissue suspected to contain blast bacteria into the white rind of a lemon fruit. The method has been very successful with materials known to contain blast bacteria, the positive reaction consisting in the formation of typical lemon black pit.

One must conclude that either the blast bacteria had died out of the spots examined, or that many dark surface spots originate from causes other than blast. While blast has not been demonstrated as occurring naturally in green leaves or stems of avocado, it is to be expected under favorable weather conditions.

During December, 1929, a rather careful examination of avocados for blast was made with Farm Advisor B. L. Smith, in the Sacramento Valley. Nothing which could be recognized as blast was found on avocado fruits or trees, and various spots and blemishes studied further in the laboratory failed to show the organism. At the same time, undoubted evidences of blast were observed in citrus. The study was made before

[36] Smith, C. O., and H. S. Fawcett. A comparative study of the citrus blast bacterium and some other organisms. Jour. Agr. Research 41(3):233–246. 1930.

[37] Smith, C. O. Blast of avocados—a bacterial disease. California Citrograph 11:163. illus. 1926.

[38] Unpublished data.

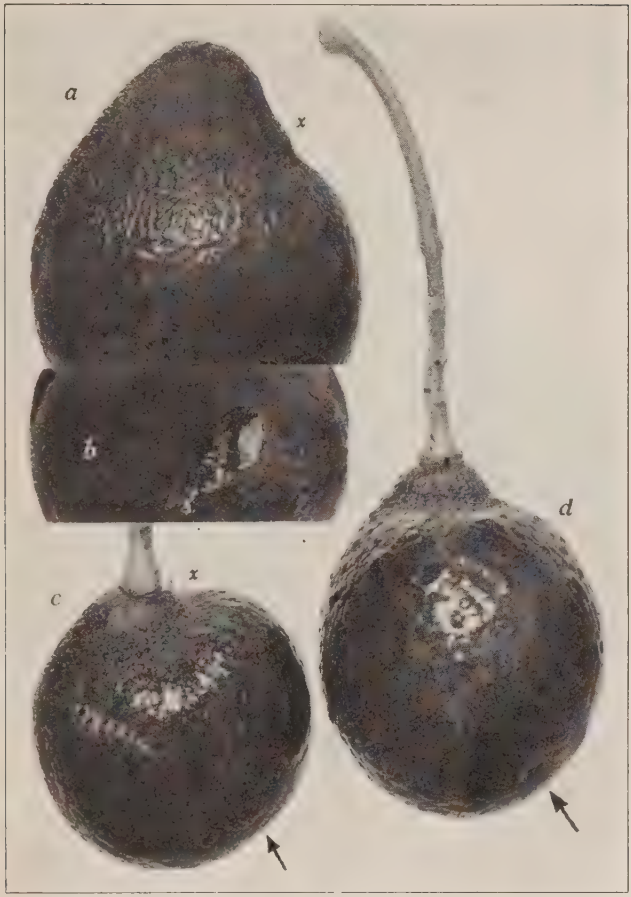

Fig. 21.—Avocado crick-side: *a*, on Anaheim, *x* marking the center of depression; *b*, view looking down on the stem scar of a fruit similar to *a*. The white portion at the right of the stem scar is the new break made by removing the fruit pedicel; and the dark portion at the left, comprising slightly more than half the area of the stem attachment, represents an old break which occurred while on the tree, with some white deposit formed below and at the left of the old break. In *c* and *d* are shown pronounced crick-side on Spinks, *x* marking about the center of depression which has been so extreme in this case that the normally high side of the fruit is actually lower than the other; and the arrow indicates the position of the stigma, which in this variety occupies a depression instead of being elevated. A fruit similar to *c* is shown at *d*, but revolved about 45° to the left to show the position of the stigma which was the upper end of the fruit at the blossoming stage.

the beginning of the rainy season, and the disease was not active. One of the most striking features of blast on citrus consists of a shield-shaped area of dead tissue on the green stem about the base of a leaf. The dead area is formed where the disease advances down the leaf petiole, killing the leaf and spreading out on the stem, often for a distance of half an inch. The lesion heals from below the bark, but the dead surface remains for several years, and is conspicuous until the surface of the twig becomes covered with brown bark. This type of blast lesion has not been observed in avocado stems.

A number of spots of fruits and twigs might easily be taken for blast. (See "Cankers," p. 24; "Carapace Spot," p. 39; "Thompson Spot," p. 42; "End-Spots," p. 51; and "Speckles," pp. 53 and 61.)

Protecting trees with windbreaks, and spraying with bordeaux before the rainy season, has helped materially to control blast on citrus, so that promising measures are available for trial if occasion should arise.

Crick-Side.[39]—Crick-side is a peculiar distortion of a specific configuration. Normal avocado fruits have an obliqueness when seen from the side, if turned to a certain position (fig. 1*g*, *j*). If the fruit is revolved about the long axis through a quarter turn (90°) this obliqueness disappears. The figure suggests a plastic body, one side of which has been pushed up and the other sagged down, so that the stigma comes to be more or less at one side of the center of the lower (larger) end. In some varieties the obliqueness is much more noticeable than in others.

In crick-side the upper half of the fruit on the high side fails to grow normally, so that this part of the fruit becomes depressed (fig. 21). The part where deficiency of development occurs shows a crowding together of the prominences which make up the pebbling in the rough fruits. Affected flesh is denser and discolors more rapidly on exposure to the air, but otherwise appears about normal. Many crick-side fruits drop while small, and others are lost from a large black spot which develops in the depressed portion. Some affected fruits come to full maturity.

The cause and essential nature of the trouble are not understood. It is thought that over-fruitful trees are more liable to have some or many crick-side avocados than less productive ones, and that trees low in vitality are more susceptible than very vigorous trees. The Spinks variety is highly susceptible and this may be in some way related to the high productiveness of this variety. The defect is seen occasionally also

[39] J. Eliot Coit first used the name "kink-neck," and the present author inadvertently changed the name to "kink-side." (Horne, Wm. T. Kink-side. California Avocado Assoc. Yearbook 1931:81. 1931.) In consultation with Dr. Coit, he has suggested the name "crick-side." This seems to avoid confusion with the name "ring-neck" which refers to a disease of the fruit pedicel (see p. 49) and to express the idea of a lack of well-being involving the side of the fruit.

in many other varieties. No record is known of its occurrence on the Fuerte which rarely sets an excessively heavy crop.

Embossment.—A blemish (fig. 22) consisting of a small elevation like a miniature mountain with a little corky tissue at the top, or of a ridge

Fig. 22.—Embossment, a round type of off-bloom Fuerte showing a pronounced elevation at the left, and numerous ridges on different parts of the fruit.

or series of ridges with a gray line at the top is not rare. It appears to be a specific kind of injury and the author has named the raised point or ridge a "boss." The affected fruit might be called "bossed" fruit, and the condition in general, "embossment." It may have some importance, since the raised parts are liable to injury. The course of development and cause of the injury have not been studied.

Ring-Neck.—Ring-neck is one of the avocado diseases described by Dr. Coit.[40] It is a blemish, usually on the fruit-stem or pedicel, consisting of irregular areas of superficial dried tissues which become more or less separated from the living tissue. It is particularly likely to affect

[40] Coit, J. Eliot. Pests and diseases of the avocado. California Avocado Assoc. Yearbook 1928:20. 1928.

the thickened segment of the pedicel next to the fruit. Sometimes a complete ring of surface tissue dies, separates from the pedicel, and peels off, leaving a scar. The upper end of the pedicel next the stem often is

Fig. 23.—Fruit pedicels showing ring-neck. All are of the Itzamna variety except the one at the extreme left which is from Benik, and has only a very small area of dead tissue at the lower end, which was next to the fruit. Nearest to the one at the left is a normal Itzamna pedicel showing the thickness and succulence, especially of the lowest segment. The black fragments are dry surface tissue which broke off in handling.

slightly fleshy and enlarged, and a small ring-neck spot sometimes occurs on it. Occasionally lesions which have somewhat the appearance of ring-neck develop on the fruit, and where extensive, may give it a grotesque appearance through curling up of the dead surface layer from the edges.

The author has not observed any case where killing of the tissue of the fruit pedicel progressed deeply enough to involve the wood fibers. It is said that some deeply scarred pedicels are weakened and break, permitting the fruit to drop, but this also the author has not observed.

Ring-neck is rather common on the Fuerte variety, and perhaps is even more striking on the Itzamna (fig. 23); but it occurs on other varieties also. Ring-neck appears to be associated with succulence of the tissues affected.

The author has not yet succeeded in observing the process of development of ring-neck spots, and the cause of the disease is not known.

The avocado sometimes has spots of dead tissue where the cause of dying is very puzzling. (See canker of green stems, p. 26.) Much small or immature fruit is shed from the tree. In some of these cases the lower segment of the fruit pedicel is black and withered while the fruit below and the pedicel above remain green. It is possible that these withered pedicel segments represent an intense phase of ring-neck, but it has seemed best to tentatively regard these as phases of shedding or abscission (see p. 39 and fig. 16*a*, *b*). If these conditions should be found to be phases of ring-neck, the disease would have to be regarded as much more important than is here indicated. It is also said that fruits with heavily ring-necked pedicels fail to develop normally and fully, so that they are of inferior grade.

At the present time no suggestions for control are available. There does not appear to be danger that the trouble will increase disastrously, but it is highly desirable that it should be studied further, and its true nature and cause made out; and, if possible, control measures devised.

DISEASES OF MATURE FRUIT ON THE TREE

End-Spots.[41]—End-spots is the name applied by Dr. Coit to the type of spoilage affecting mature fruits on the tree in which the lower (larger) end withers gradually and dries. It appears that two principal influences are involved: first, an over-maturity or senility affecting the skin of the lower part of the fruit, as pointed out by Dr. Coit; second, desiccation of the surface under conditions of pronounced water deficit in the plant. Regardless of which influence is preponderant, once the surface is killed drying out progresses gradually through the skin and underlying flesh.

The first condition the author has observed in Blake fruits maturing in August and September, or later, when small spots develop about the lower end of the fruit, at first about 1 to 3 mm. in diameter, obscurely

[41] Coit, J. Eliot. Pests and diseases of the avocado. California Avocado Assoc. Yearbook 1928:21. 1928.

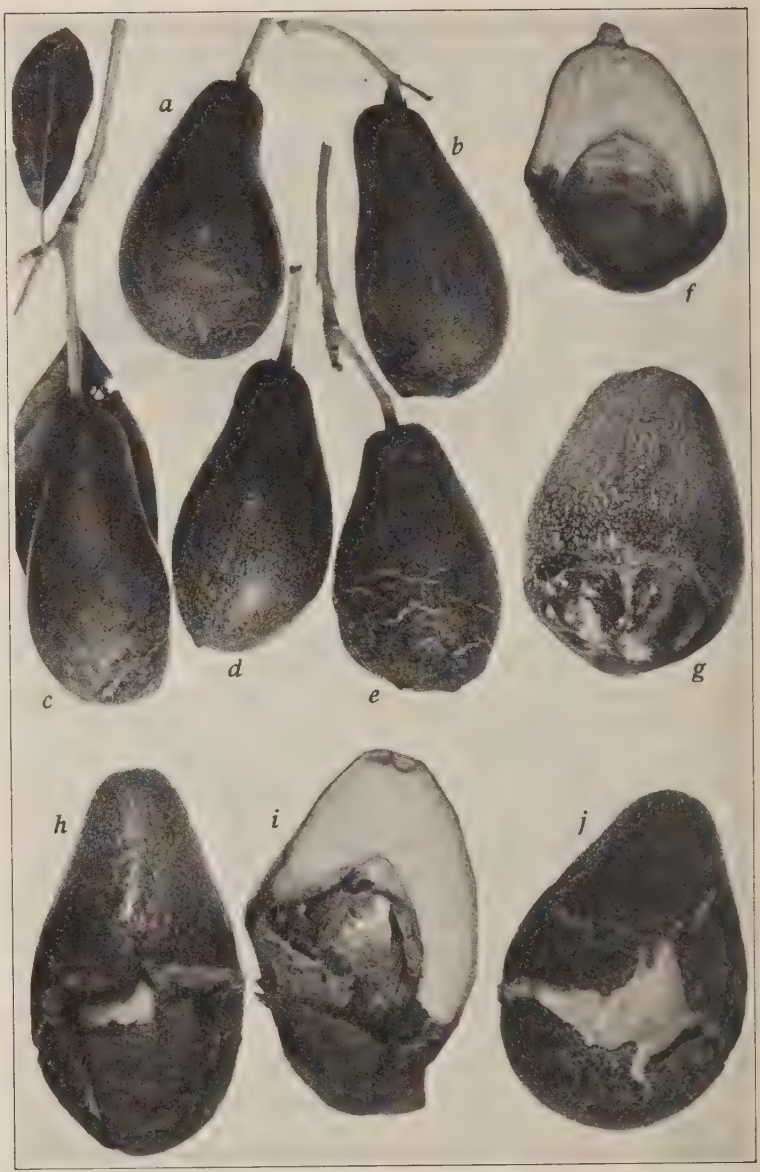

Fig. 24.—End-spots are shown at *a* to *e*, except *d*, which is normal on Blake. In *f*, Puebla, is shown the condition of the flesh in old end-spotted fruit, with *g* showing surface view. An end-spotted Fuerte of long standing in which cracking has proceeded so far that the seed is exposed is seen at *h*, with a section of the fruit at *i*. An end-spotted fruit of the variety Ward with the shell widely cracked and partly separated, is shown at *j*.

smoky, not sunken, superficial, and with a vague margin. These areas spread and coalesce and a general drying out follows, with withering, cracking, and desiccation (fig. 24 *a–e*).

A somewhat different phenomenon occurs in Fuertes, in early stages of maturity along with the desiccating winds of late autumn and early winter. Speckles (fig. 25*c*) appear in abundance on the green surface. These speckles are small, dark spots, usually $\frac{1}{16}$ inch in diameter or less, depressed, and clearly outlined. They are caused by a local collapse and drying out of the surface tissues. They are not areas of decay, and do not indicate a deterioration of the flesh below. In the end-spot of Fuerte, described here, speckles become numerous about the lower end of the fruit and coalesce to a large black spot or area (fig. 25*a, b*). If the fruit is picked soon after the formation of this spot, the flesh is not appreciably involved, but drying out progresses from the surface, and extreme and grotesque conditions may be reached (fig. 24*h, i*).

In the second type of end-spots just described, apparently no visible breakdown of surface tissue appears before the local drying out causes collapse. This kind of end-spots is apt to be particularly severe in trees much exposed to wind and especially if soil moisture is deficient. Fruits hanging well sheltered among the leaves are affected as well as those exposed to wind and sun, indicating that the stress from water deficiency is general throughout the different parts of the tree. More water is doubtless lost by the leaves than by the fruit, and the fruit probably suffers from withdrawal of water through the stem as well as by evaporation.

As pointed out by Dr. Coit, varietal behavior is important with regard to end-spots. Some varieties mature at the lower (larger) end before they do at the upper and so may be lost before attaining full maturity. Blake, Ward, Ganter and others have a short period of maturity before end-spots appear, whereas certain varieties as the Fuerte may remain on the trees in good condition for several months.

Some varieties may give striking figures, as the Ward, in which large cracks may appear and much of the shell may separate and peel off, leaving the fruit covered with a false skin composed of the dried outer surface of the flesh (fig. 24*j*).

Control of end-spots apparently must consist in maintaining the tree in normal condition, especially as to moisture supply, and in timely harvest. While slightly end-spotted fruits may be little or not at all impaired for home use, it would seem that they must always be culls from the commercial viewpoint, owing to danger of injury and susceptibility to infection with decay fungi, especially rhizopus. (See "Rhizopus Rot," p. 58.)

Fig. 25.—End-spots: *a*, section of Fuerte fruit showing the superficial character of the breakdown in early cases; *b*, the surface of the same fruit as shown at *a*; *c*, end-spots on Dorothea showing an early phase of end-spots as speckles and cracking; *d*, round-type Dorothea fruit with end-spots and cracking.

(For spots affecting immature fruits, see discussion of canker spots, p. 24; "Carapace Spot," p. 39; and "Thompson Spot," p. 42.)

Hollow Fruit.—Fruits of the large Guatemalan varieties are occasionally found which have rather firm shells in which depressions occur about the lower (larger) end. Although the fruit may show no visible

Fig. 26.—Hollow fruit of the Anaheim variety. Although the surface of the lower end has depressions, it is not dried or broken at any point

break on the surface it is usually found to be partly hollow. When cut into, flesh at the lower end is withered and shows cracks and darkening. In earlier or less pronounced cases, no abnormality of flesh may appear. This has been observed especially on Lyon, Anaheim, and Itzamna varieties, which tend to overbear. It is thought that the plant is overtaxed by the demands of these large fruits for water, and perhaps for nutrient materials, and that breakdown comes in the flesh rather than in the shell. While the shell remains intact, no infection occurs and the flesh merely dries and withers (fig. 26).

It is probable that certain varieties will need thinning of fruit to avoid overtaxing tree vitality, especially in the case of young trees. Possibly, also, it may be due to some acute temporary stress, or to some abnormal or unhealthy condition of the tree.

Dr. Coit has called attention to a condition of mature Puebla fruits in which open spaces or cavities are formed passing longitudinally

through the flesh following the fiber groups. Practical avocado handlers have called these air pockets (fig. 27). These open spaces extend from the vicinity of the stem toward the lower end of the fruit and rarely go beyond the thick part of the fruit. Some of the spaces, however, follow the fibers to the point of attachment of the seed. It is observed that the

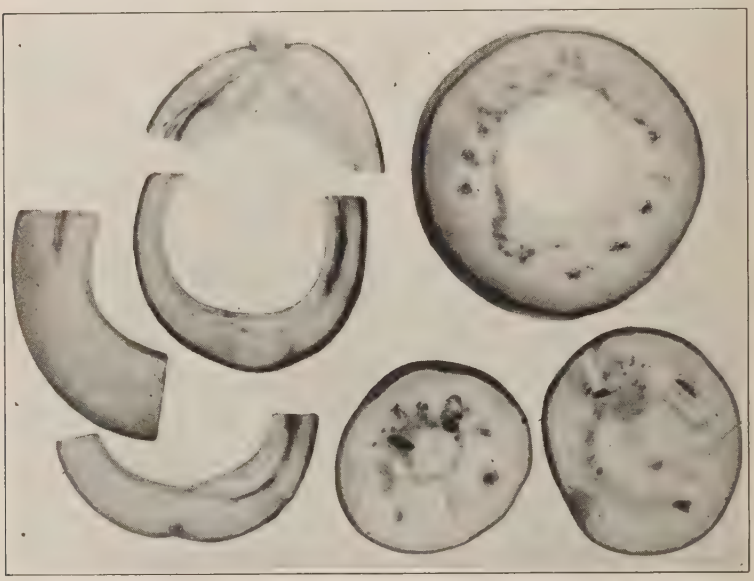

Fig. 27.—Hollow fruit (air pockets) of Puebla associated with dark fiber areas. The large section at the upper right shows this condition in one fruit, just above the thickest part. Two small cross sections represent the condition near the stem. The longitudinal section at the extreme left shows a cavity ending near the thickest part of the fruit. The longitudinal section at the lower left shows the cavity extended to the surface of the flesh at the point of seed attachment.

open space is surrounded in most, if not all, cases by a greater or less area of umber-colored tissue. Where the open cavity does not extend very far, it is found that the darkened area is continued beyond it. Also, many fiber groups have the darkened tissue but no open cavity. Where the umber-colored streaks are numerous, a zone of somewhat hardened flesh is formed. Whether the cracking indicates a stress arising from water removal by the fibers to the stem, or whether the brown discoloration is a breakdown owing to some other cause, and desiccation along the fibers is an incident, is not certain. Whether this is a phase of the Puebla flesh darkening which caused severe losses in December, 1931, is not known. It is believed that desiccating winds have been sufficiently severe shortly before the appearance of this condition to cause pronounced water deficiency in the tree and fruit.

Sunburn.—One of the commonest defects of avocado fruits is due to exposure to the sun. Some fruits show an extensive lighter-colored area on the side most fully subjected to the sun's influence. The color may be pale or yellowish, and often in the center is an extensive dead area. (See also p. 19 for burn on leaves and twigs.)

There seem to be no especial precautionary measures available to avoid this trouble. In some places where production is heavy, it is customary to knock down the most exposed fruits at the top of the tree while they are small.

Senility or Old Age of Fruit.—In addition to certain breakdowns, such as end-spots which occur after full maturity, conditions of the fruit have been observed which we have referred to as senility. In the Fuerte, senile fruits become somewhat dull and grayish in aspect and when picked they do not soften normally. Softening is tardy, coming first just below the skin, and a stale odor and taste develop. It is possible that the conditions to which we have applied the name senility are owing in part to climatic or other influences and not alone to the length of time which the fruit has remained on the tree. The practical harvesting problems arising from senility are now well recognized,[42] but the scientific information which should serve as a background for development of the practical skills is very incomplete. (See also "Dothiorella Rot," p. 60, and especially "Black-Crack," p. 62.)

Lenticel Cork.—A condition of the surface of Guatemalan fruits is shown in figure 16*c*. It consists of a corky enlargement of lenticels, especially about the lower end of the fruit. It occurs in the interior districts, but less toward the coast. It is believed to increase after maturity and in extreme cases to finally cause drying, cracking, and loss of fruit.

Microscopic examination of a vertical section of the spots shows that drying out penetrates only slightly into the skin, and that the brown dead tissue is bounded underneath by a cork layer which apparently checks downward advance of the deterioration. At the edges of the spot, below the epidermis, the dark deteriorating condition extends laterally beyond the limit of the surface spot and is not bounded by a cork layer at the margin. Depth of the brown dead tissue is about 10 cells at the margin. Below this depth the cork layer is formed from beneath. Texture of the dead tissue appears less compact than should be the case if death were due to simple drying. A slender hyphomycetous fungus has been observed in the dark, disorganized tissue.

Study has not progressed far enough to justify any conclusion concerning the cause of the disease, nor to suggest control measures.

[42] Stephens, B. C. Fruit maturities and packing problems. The Calavo News, p. 1, 4. Oct., 1934.

DISEASES OF HARVESTED FRUIT

In the author's observation, avocados do not soften while they remain on the tree, although a limited softening may occur in the vicinity of wounds or other injuries. When removed from the tree and kept under favorable conditions softening begins after a few days, usually about a week at ordinary temperatures. As fruit softens, various declines may occur such as a darkening of the surface in vaguely defined areas. Such darkening is usually referred to as "scald." About the lenticels, small, sharply defined areas may become slightly sunken and dark. The author has named these spots "speckles." They may appear also while the fruit is on the tree. Speckles are mainly local desiccation phenomena, but doubtless other factors are concerned also. They evidently are not caused by fungi, or bacteria, though frequently infection starts in a speckle.

Decays due to fungi may develop, especially if there are wounds. Surface moisture and high temperatures also increase the chance of loss. Only a few specific fungus decays are described in this bulletin, but many others exist. Final decomposition of avocado fruits is largely caused by bacteria.

Rhizopus Rot, Black Mold, or Bread Mold Decay.—The common bread mold (*Rhizopus nigricans* Ehr.), which causes rot and "leaking" of strawberries, peaches, sweet potatoes, and many other fruits and vegetables, is the most active destroyer of soft avocados yet observed. The fruit is not affected until it begins to soften. Infection is usually at a wound or the stem scar, but may be by contact with another decaying fruit. An affected fruit decays rapidly, and if the air is dry, only very dense, short, dark, felt-like mold appears in spots on the surface, usually occupying depressions or protected places. If the atmosphere is moist, very long, gray mold appears (fig. 28).

If the air is moist, the mold on the surface advances more rapidly than through the flesh. Under favorable conditions the decay may advance in soft flesh as much as an inch in two or three days. The boundary separating the sound from the decayed flesh is not clearly marked, making it difficult to know how to trim fruits with this decay. Somewhat more flesh should be discarded than appears to be necessary, if all the fungus is to be eliminated.

The rotting fruit usually exudes more or less liquid, *i.e.*, "leaks." The flesh becomes watery and limp but somewhat tough, and if a piece is tasted the harsh fungus threads can be felt on the tongue in contrast with the smooth texture of the normal flesh. Odor is peculiar and un-

pleasant, but unlike the rancid odor of dothiorella rot (see p. 60), or the putrid odor of bacterial spoilage (see p. 69).

In rhizopus-rotted fruit the seed is not affected, and it is uninjured for planting.

Fig. 28.—*Rhizopus* rot showing development of the fungus in moist air. Infection took place on the lower end of the fruits and was rapidly spreading upward. The small black dots are the sporangia in each of which many spores are formed. When the sporangia break, spores are liberated to float about in the air.

Control measures consist in preventing wounds, avoiding surface moisture, and keeping the fruit as cold as is safe. The practice of placing a drop of wax on the cut stem area should be helpful, especially if the button has been broken out. If the surface to be waxed is first wet with alcohol or other good disinfectant, protection should be still more effective, especially if the wax is at a high temperature.

Experiments with guinea pigs and rats made several years ago indicated that avocado flesh with rhizopus decay is not poisonous.[43] Only small amounts would be eaten even if decaying fruit should be trimmed

[43] Horne, W. T. Avocado fruit decay. California Avocado Assoc. Rept. 1925–26: 96–99. 1926.

carelessly; rhizopus rot therefore does not appear to constitute a menace to health.

Dothiorella Rot or Surface Rot.—The kind of rot here called dothiorella rot or surface rot has been the most troublesome avocado-fruit decay yet observed in California, as affecting marketing operations. It is by no means so universal, nor so rapidly destructive, as rhizopus rot (see p. 58), but it appears at an earlier stage of softening. It is not dependent on wounds or high temperature. In severe forms, numerous spots rapidly cover the surface of the fruit. Where not otherwise important it often causes a serious rot of the stem scar or eye.

Dothiorella rot probably occurs throughout California wherever avocados are grown, but it has been observed in serious amount only in the moist coastal areas. The author's observations indicate that it is closely associated with tipburn. The loss of off-bloom senile fruits has probably been ascribed to dothiorella in some cases when these fruits would not have softened satisfactorily, even if dothiorella had not been present. On senile off-bloom Fuertes the decay may develop before the flesh is soft enough for use.

Ordinarily, dothiorella rot does not appear in fruit hanging in the tree nor in harvested fruit before the "breaking" stage, that is, the earliest detectable softening. Dothiorella spots when first noticeable are medium dark (umber) in color, usually about $\frac{1}{12}$ inch in diameter, not sunken nor sharply bounded (fig. 29*b*, *c*, *f*). In two or three days a spot may spread to $\frac{1}{2}$ inch or more, keeping the same character. After this the spot continues to spread, but becomes softened so that the outer skin is easily broken and the color of the surface may become somewhat gray-green, especially if slightly moist. There is a settling of the surface and it becomes uneven. Minute pustules appear in the surface, often crowded and irregularly grouped (fig. 29*h*). If the fruit is somewhat dry the color may become dark. Tufts of felty to cottony fungus mycelium may grow out of the pustules, if the air is not too dry, and completely cover the surface (fig. 29*g*). The felty or cottony fungus is at first white, but becomes gray or dark. Sometimes, with the aid of a lens, minute drops or beads of dull white can be seen exuding from the pustules. These drops may take the form of minute coils (fig. 30*d*).

Dothiorella rot spreads downward into the flesh less rapidly than it does in the rind (fig. 29*a*). Affected flesh is somewhat moist and greenish, with texture soft instead of firm and buttery, and becomes somewhat shrunken. The rot merges gradually into the sound flesh with no distinct line of demarcation. The odor is rank and unpleasant.

Some Fuertes develop hard, black spots of varying sizes, often large. These are particularly noticeable on old off-bloom fruits which have

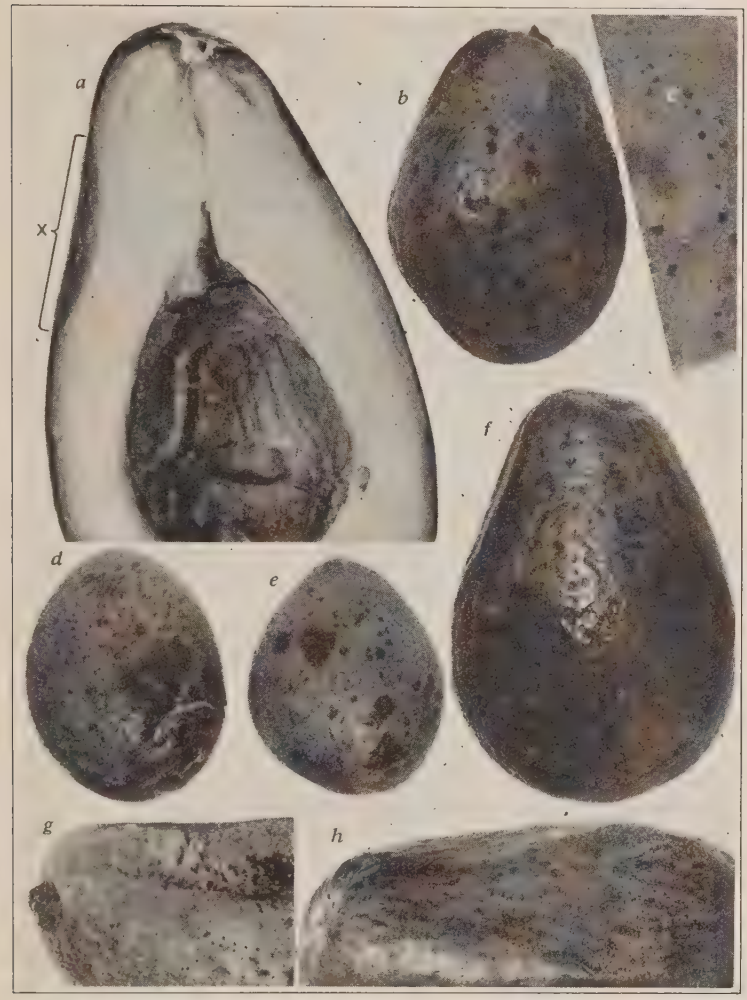

Fig. 29.—Dothiorella rot: *a*, longitudinal section of soft Fuerte through a spot of dothiorella rot at *x* showing that the rot penetrates into the flesh more slowly than along the surface (the spot on the opposite side of the fruit is a bruise); *b*, very young dothiorella spots on off-bloom Fuerte; *c*, a group of dothiorella spots near the center which started in speckles but developed vague margins, surrounded by noninfected speckles which are small, dark, and clearly bounded; *d* and *e*, two small senile off-bloom Fuertes, newly picked, showing large, hard, black spots which are probably not caused by dothiorella but represent the disease black-crack (see p. 62); *f*, Dorothea variety showing many small and large areas of dothiorella rot; *g*, part of the surface of a fruit kept in moist atmosphere, decayed by dothiorella, and the fungus grown out into a fine white to gray felty surface mold; *h*, as at *g*, but decaying fruit kept in a drier atmosphere—only pustules formed with no white felty mold.

been on the trees through the winter (fig. 29*d*, *e*). Whether these dark areas are caused by dothiorella is doubtful, since some fruits from areas where dothiorella is not abundant have dark spots in which the fungus apparently is not present. Also cultures from these spots in some cases do not give dothiorella. However, in coastal areas, the dark spots often become typical areas of dothiorella rot when the time for softening of fruit comes. (See "Senility," p. 57.) These black areas seem to constitute a distinct disease, probably not due to a parasite. This may be the disease referred to by Dr. Coit as "Black-Crack."[44]

On thick or moderately thick-shelled fruits, dothiorella rot may show a somewhat different aspect, appearing to be more in the nature of a wound infection or distinct deep spot in which decay comes with softening, as described above, but apparently somewhat earlier. This phase has not been investigated.

The manner of infection in dothiorella rot has not been fully studied, but it seems probable that the spores germinate and the fungus threads penetrate into the spaces below the flecks or lenticels in the skin of the fruit while it is on the tree. Treatment of the firm fruit with hot water or disinfectants which may be severe enough to injure the skin have not prevented the development of dothiorella rot. Wetting the surface with alcohol and burning this does not prevent the growth of dothiorella fungus. There is evidence that not only dothiorella but other fungi also may penetrate the lenticels and produce decay as the fruit softens.

Where fruit is taken from the tree in perfect condition, and taken at the earliest permissible stage of maturity, dothiorella rot appears to develop at a later stage in softening than is the case with fruit held long on the tree after attaining adequate maturity for utilization.

The fungus[45] causing dothiorella rot in avocados also causes dothiorella rot in citrus fruits, and melaxuma or black sap disease in walnuts. It occurs in dead twigs of various plants, but dead twigs of avocado (see p. 29, p. 11, fig. 3 and fig. 30) furnish the most favorable media for its development. Fruiting bodies of the fungus may be observed as minute dark points in the surface, and if a little of the surface is cut away so as to cut through the black points, the minute dark bodies are seen to have white centers (fig. 30*a*, *c*). These fruiting bodies are really of two kinds though similar in appearance. In one kind (pycnidia) spores are formed, one each at the end of short fungus threads. These spores break off and are pressed out in a soft mass as a minute drop or coil, under

[44] Coit, J. Eliot. Pests and diseases of the avocado. California Avocado Assoc. Yearbook 1928:21. 1928.

[45] It has been identified as *Dothiorella gregaria* Sacc. or, more recently, and since the discovery of the asceus-bearing stage, as *Botryosphaeria ribis chromogena* Grossenbacher and Duggar.

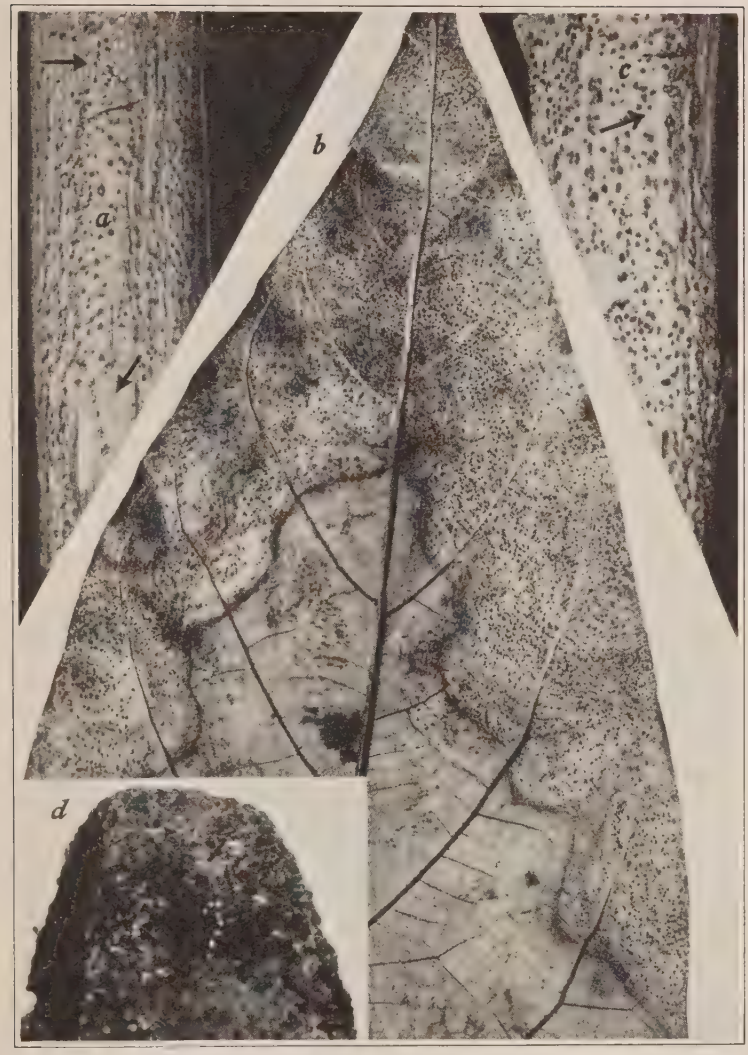

Fig. 30.—Dothiorella rot: *a* and *c*, dead avocado twig (enlarged) showing fruiting bodies of dothiorella breaking through the surface as small pustules, the arrows indicating areas where the surface has been shaved by a shallow cut parallel with the surface and showing the white centers of fruiting bodies with black surface covers; *b*, avocado leaf (enlarged) with a tipburned area and dothiorella fruiting bodies showing as dots in the dead area; *d*, lower end of a seedless Fuerte ("cuke," "pickle") which has rotted with dothiorella and then dried showing two spore coils indicated by the arrow—the spore masses about ½ inch above are in less perfectly formed coils, and those still further up at the right are in the form of irregular masses. (Photographs for *a* and *c* by Dr. Ira Ayer and D. F. Palmer; for *d*, by L. J. Klotz.)

moist conditions (fig. 30*d*). The other kind of fruiting bodies (perithecia) form enlarged fungus threads or sacs, in each of which 8 spores develop. These spores are similar to the ones previously described but are broader and can usually be distinguished. Generally the pycnidia are more abundant on decaying fruit and on dead areas of leaves. The other kind (perithecia) are more abundant on dead twigs.

The spores are shot out from the perithecia to a distance of about ½ inch. Abundant moisture is necessary for shooting of the spores. Evidently spores could be distributed within a tree and spread over the fruit by dripping and spattering, but might be carried from one tree to another by wind under very moist conditions.

The problem of preventing dothiorella rot has not been fully solved but it is believed that some progress has been made. While it occurs widely, it is believed that it will not be seriously abundant, except in the more moist areas, as those near the coast. Studies carried on in connection with the spray program show that overhead irrigation seriously increases the trouble, in the coastal area. It is believed also to be much increased by tipburn (see p. 9). Even where tipburn is severe there is reason to believe that the fungus may be much reduced by thorough removal of dead twigs.

It is believed that fruits left on the tree after reaching marketable maturity become increasingly subject to dothiorella rot. Fuerte trees near the coast may blossom irregularly through the fall and winter. Fruit set during this period matures irregularly. Since there seems to be no way to tell accurately the age of this off-bloom fruit, its harvesting becomes difficult. By August some of it has become pronouncedly senile so that it decays before fully softening. Systems of marking the off-bloom fruit by colored sprays have been suggested but not perfected.

Dipping the newly harvested fruit in various fungicides and in hot water has been tried without success. Treating the harvested fruit with fungicidal gases has been tried but a successful procedure has not been worked out.

Spray programs have been carried out by Dean F. Palmer[46] of the San Diego County Commission of Agriculture, coöperating with the University. A bordeaux spray program gave complete commercial control, but 10 applications had to be made to cover the fruit continuously. The result of spray treatments which were considered practicable have not been sufficiently consistent to justify recommending a spray program. Bordeaux mixture, however, in laboratory studies prevents germination of dothiorella spores. If the fruit on the tree can be kept covered with bordeaux, it should be saved from infection.

[46] Palmer, Dean F. Description of spraying experiments. California Avocado Assoc. Yearbook 1932:44–46. 1932.

Fig. 31.—Anthracnose from artificial inoculations with a strain of fungus from mango fruits, grown in Florida and shipped to California; *a*, Blake; *b*, Mexicola; *c*, section of *a*; *d*, section of *b*.

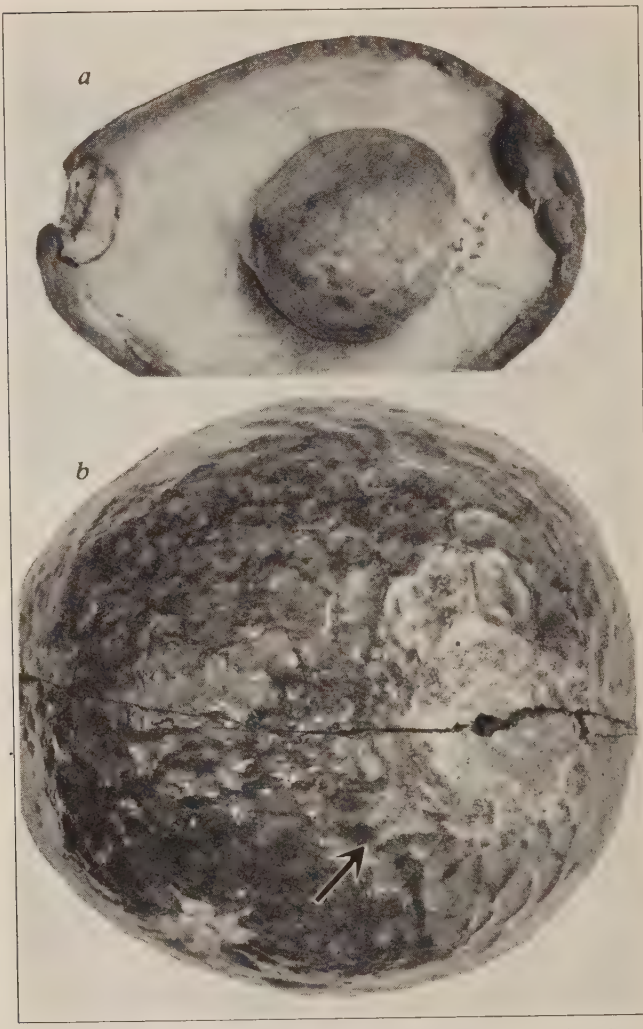

Fig. 32.—Anthracnose rot on soft Dickinson fruit: *a*, section showing decay at the stem area and in two or more confluent spots at the opposite end. Stiffness of the shell does not permit it to sink down as the flesh decays. The arrow in *b* indicates a patch of pustules of anthracnose fungus.

In some localities where the control of dothiorella rot has become a problem, it is considered desirable to fumigate the trees with hydrocyanic acid gas for control of scale insects. It appears to be the belief of most of the authorities that cyanide fumigation following the applica-

tion of copper sprays may cause injury even after several years have elapsed.[47] A zinc-lime spray material, made by substituting zinc sulfate for copper sulfate in the formula for bordeaux, has given good promise; but it has not yet been possible to fully test the efficiency of this fungicide.

Anthracnose Rot.—Anthracnose caused by *Colletotrichum gloeosporioides* Penz., is one of the most frequent rots of softening (ripe) avocados observed in California. On green-colored fruits it begins as a dark or tan-colored area. On dark fruits it usually causes the color to become somewhat lighter. In early stages it somewhat resembles dothiorella rot (fig. 31*a*, *b*). As the decay advances, if the fruit is in a moist atmosphere, minute pustules develop (fig. 32*b*) and on these pink spore masses appear. The color varies widely, according to the amount of moisture present. If moderately moist, the spore masses spread out in a pink layer; but with more moisture the color is obscured. A powdery, pink spore mass, especially in very old, decayed avocados, is usually a different fungus, namely, *Cephalothecium*. In dothiorella rot where spore masses are found they are a dirty white. In other countries anthracnose produces dead spots on young green leaves, twigs, and fruits (see p. 16 and p. 39), but the author has not observed this injury in California. The fungus has been found in dead areas of leaves, twigs, or fruits, but only in two cases studied did it appear possible that the fungus may have attacked fruits on the tree.

From limited observations made, it appears that anthracnose rot advances more slowly in the surface of the fruit than dothiorella rot, but it goes deeper (figs. 31 and 32). It is not so moist a rot and the characteristic rancid odor of dothiorella is wanting.

Sources of spores for fruit infection are about the same as with dothiorella (p. 60). The fungus bodies in the dead twigs and dead areas of leaves in the tree have somewhat the appearance of dothiorella. Dissemination of spores is more by dripping and spattering than in dry air. The stage in which spores are shot into the air has been observed only a few times, and in these cases identification of the fungus was not verified.

Studies for the control of anthracnose rot in avocados have not been made but it is thought that surface injuries or free moisture on the fruit will be likely to favor the anthracnose. Severe drying of fruit which is being held for softening is not recommended.

Miscellaneous Fruit Decays.—From time to time various sorts of decay have been observed. Many different fungi have been found associated with these decays, but detailed studies have not been made. Fungi

[47] Quayle, H. J. Bordeaux spraying and fumigation injury. California Citrograph 18:166, 184. 1933.

tentatively identified as *Alternaria,* of which several species occur, and several forms of *Cladosporium,* are common. These, and species of *Fusarium* or somewhat similar forms, occur in eye rot (decay from the stem scar) or in wounds and are apparently of general distribution, being about as common in fruit from interior districts as from the coast. In this way they differ from *Dothiorella.* In cultures, and sometimes about the decaying areas, these fungi produce gray, cottony molds or dense, dark-green felty molds, while the *Fusariums* are usually light.

A rather striking fungus, apparently in some ways similar as to the decay produced to anthracnose, is a species of *Pestalozzia.* Where it produces spore masses, these may be in tiny drops, or in distinct coils, and are coal black; whereas the spore masses of anthracnose are pink or flesh color, and those of dothiorella are dull white. The mycelium of this *Pestalozzia* where grown in culture, or as sometimes seen in decay areas, is silky and snowy white.

The green mold of apples and pears, *Penicillium expansum,* which also attacks grapes and various fruits, is frequently found to cause avocado decay, but it is not very aggressive nor does it apparently start very early. Also, the blue and green molds of citrus fruits (especially the latter) do not grow aggressively on the avocado.

Several years ago, Dr. J. T. Barrett found the brown rot fungus, *Phytophthora citrophthora,* attacking avocados in the field. The author was able to infect fruit artificially with this. A tough, light-brown decay which spoils the fruit rather rapidly was produced. Fruit on or near the ground during cool rainy weather might suffer badly. Spraying the low-hanging fruit and the ground with bordeaux, as for citrus, should prevent or check this trouble. Since this fungus does not require a wound to gain entrance, and it probably also will be able to invade fruit of any degree of maturity, it might easily cause heavy losses of low-hanging fruit, during very wet periods. It is somewhat surprising that this decay has not appeared in an important amount. Perhaps the heavy cover of leaves, which accumulates below avocado trees, serves as a mulch to prevent spattering of the fungus spores from the soil to the tree.

Several years ago, a species of *Diplodia* was found in avocados from Florida which caused an active, rather dry, dark rot, and which attacked the seed as well as the flesh. A fungus of this kind is active in citrus fruits in California under rather special conditions of moisture. While we have not found this in California avocados, it will doubtless appear, under favorable conditions.

The fungus which causes green rot of young apricot fruits, *Sclerotinia sclerotiorum,* and the gray mold of stone fruits and others, *Botry-*

tis cinerea, are able to attack the avocado when fruits are artificially infected, but have not yet been observed to do so in nature.

It is probable that a great number of fungi and bacteria, in fact probably most of the saprophytes, may grow on the soft (ripe) avocado flesh. It is also true that the sound, firm fruits hanging on the tree have been remarkably free from fungus or bacterial decay. Even where wounds occur on normal fruits on the tree, as by wind injury or biting by animals, decay rarely starts, owing, apparently, to the ability of the living tissue to heal the injured surfaces.

The care given in handling of citrus fruits to avoid extremely minute surface injuries apparently is not so important with the avocado, since this care is directed mainly against the green and blue molds of the citrus fruits which are only very minor enemies of the avocado. At present, the principal measures for preventing loss of fruit are: to avoid cuts and bruises; to avoid surface moisture; and to keep the fruit at a favorable temperature. (See "Temperature Relations of Harvested Fruit," p. 72.) Washing the fruit in disinfecting solutions and also in hot water has not yet been shown to have much value. Coating the fruit with waxy or other substances has not been of much benefit. Heavy waxing of firm fruit prevents softening and brings on offensive spoilage.

Flesh Darkening.—The matter of dark-colored flesh in avocados has not been investigated in detail, so far as known, and its causes and nature are not understood. Darkening may consist in a generalized dulling and graying of the flesh color. It may develop in sharply marked areas along the fibers which pass out from the stem into the flesh. It may affect the fibers only. Or, it may be distributed in other figures. It may probably follow various sorts of injuries. In fruit which had one end artificially frozen, it was noted that the flesh which had been frozen failed to soften, and strong blackening developed in the tough flesh just back of the boundary of frozen and nonfrozen flesh. (See fig. 34 and p. 72.)

One seedling Mexican tree has been observed on which the later and more mature fruits showed a generalized graying and limited darkening of the flesh as the fruit softened. This fruit matured early enough, and blossoms came late in the spring, so that neither frost nor chilling could well have been concerned. The darkening of this fruit had some resemblance to that of the Spinks variety which has been discriminated against commercially because of this behavior. The darkened flesh is not impaired in flavor, so far as noted in this type of darkening, but the loss is in appearance only.

Where darkening of flesh is found in summer-maturing Guatemalan fruits, it would be difficult to ascertain whether or not the condition

may be due to frost (or at least to chilling) since this fruit has been exposed in full-grown condition during the winter season.

A striking case of flesh darkening in Pueblas occurred in December, 1931, and later in the season, causing a serious loss in the remaining crop. The darkening was strongly developed and more or less localized in the lower part of the fruit and extended along the fibers (fig. 33). It was more or less associated with hard flesh. It was first thought that the

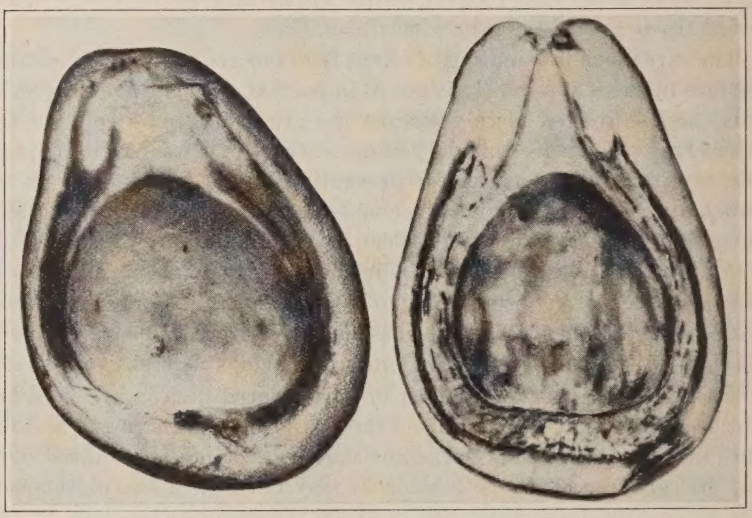

Fig. 33.—Two Pueblas from the late crop of 1931. These were said by the trade to "cut black." Many fruits, especially like that at the right, failed to soften; particularly in the area between the darkened fibers and the seed. This condition was present in fruits newly taken from the tree.

trouble was caused by the freeze of November 22 and 23, but reliable reports have been received of its occurrence in orchards where tomato plants were not injured. A few hard-fleshed Pueblas appeared in January, 1933, but the behavior is an unfamiliar one. Fruits were supported in cloth bags, and some remained on the tree until March 29, 1933. The later fruits showed some small areas of dark flesh, but there was no general and severe blackening in the oldest fruits. The trouble may increase with advance of the season, but it is not a simple effect of senility or old age of the fruit. B. C. Stephens of the Production Department, Calavo Growers of California has made the suggestion that the outbreak in 1931 was connected in some way with the high temperatures of the summer and autumn preceding its appearance, and perhaps with other special conditions of that year.

Many cultures made at different times and from diverse material in-

dicate that flesh darkening is not caused by the presence of ordinary fungi or bacteria. Direct microscopic examination has thus far failed to

Fig. 34.—Cold injury—effect of freezing on mature, but firm Puebla fruit. The pedicel and upper end were introduced obliquely into the freezing compartment of an electric refrigerator until frozen (17 hours). The lower part of the fruit was not frozen. The frozen part turned dark, dried considerably, and did not soften. The lower part softened normally, as shown by the depression made with a pencil on the right half.

throw light on the nature and cause of dark flesh. (See "Frost or Cold Injury," p. 72; and "Senility," p. 57.)

Different types of flesh darkening presumably have different causes, but the type mentioned in the Mexican seedling at the Citrus Experiment Station (p. 69) is probably a varietal one. Maintenance of an attractive flesh color under varying conditions and through a long sea-

son would seem to be an important characteristic in a commercial variety.

Temperature Relations of Harvested Fruit.—According to Overholser[48] the mature Fuerte avocado fruit freezes at about 29° to 28° F. Thoroughly frozen fruit may be kept for a long time, and is unchanged while frozen. Upon thawing, if previously softened, it immediately breaks down.

Overholser found that if fruits of the Fuerte variety in firm condition were stored at temperatures much lower than 45° F they did not soften, but after a time withered and the flesh turned dark. After being kept for a time at the lower temperatures, and brought to a warmer atmosphere, the fruits lost their power to soften normally, and they gradually declined. The Royal was the only variety tested which could endure 32° without injury. Fuerte fruits softened slowly but normally (in 3 or 4 weeks) at 45°; when fully soft they could be stored at 32°, and kept for a similar time without injury.

ACKNOWLEDGMENTS

Assistance in the study of avocado diseases has been received from Dr. Howard S. Fawcett, who turned over his notes and materials at the beginning of the work in 1928 and who has given all possible help and support to the project. Dr. E. R. Parker of the Division of Orchard Management in the Citrus Experiment Station has coöperated in many ways, and has read the preliminary draft of this publication. Dr. J. Eliot Coit has freely supported the work and has made valuable suggestions during the preparation of the bulletin. Mr. Dean F. Palmer, Agricultural Inspector in San Diego County, who is coöperating with the University, has been particularly helpful in studies of dothiorella rot, tipburn, and some other troubles.

The California Avocado Association has published in its Yearbooks such information as we have had ready for distribution, and has in other ways given constant encouragement. The Calavo Growers of California (the coöperative marketing organization of the growers) has supported the work in various ways, especially with fruit for experimental purposes. The farm advisors and agricultural commissioners of avocado-growing counties, as well as many growers and avocado enthusiasts, have also assisted generously.

[48] Overholser, E. L. Cold storage behavior of avocados. California Avocado Assoc. Ann. Rept. 1924–25:32–40. 1925.
Overholser, E. L. Cold storage, ripening, and respiration studies of the avocado. California Avocado Assoc. Yearbook 1929:137–140. 1929.

15m-1,'35